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Movements and Behaviors of Resident and Translocated Northern Map Turtles (Graptemys geographica) in the Upper Niagara River with Artificial Basking/Nesting Platforms as a Management Strategy

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Movements and Behaviors of Resident and Translocated Northern Map Turtles (*Graptemys geographica)* in the Upper Niagara River with Artificial Basking/Nesting Platforms as a Management Strategy

A Thesis in
Biology

by

Chelsea L. Moore

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Master of Arts
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ABSTRACT

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Urbanization and degradation of riparian zones has contributed to the decline of fish and wildlife populations throughout the world. Northern Map Turtles (*Graptemys geographica*) in the upper Niagara River face similar declines due to shoreline development and the concurrent loss of backwater habitats and terrestrial nesting sites. A project was initiated in which basking/nesting platforms were created, and Northern Map Turtles from a Lake Erie population were translocated into the river. Resident and translocated turtles were tracked using biotelemetry and their habitat use, behaviors, and swimming paths were compared. Translocated turtles exhibited homing behavior and had longer home ranges than resident turtles. However, both translocated and resident turtles used similar swimming paths in the river, spent time in restored habitats, and used the Strawberry Island Complex when crossing to opposite shorelines. Water temperature, photoperiod, and turtle body mass may influence the change in activity level of Northern Map Turtles. Becoming active in the spring was more compressed temporally than brumation initiation but remained the same thermally. The basking/nesting platform deployed in the urban habitat was used by Northern Map Turtles for basking, but no nesting occurred. The strong water current velocity at the headwaters of the Niagara River, in conjunction with the Black Rock Lock, create a barrier between the river and lake habitats, and turtle populations in the river are isolated from their conspecifics in Lake Erie. The strong current may also funnel turtles from Lake Erie into a habitat at the headwaters of the Niagara River that is characteristic of an ecological trap. The lack of local reproduction and the asymmetrical dispersal of turtles was characteristic of a sink population, as well.

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Introduction

Humans have physically altered river systems throughout the world to exploit the most economically beneficial ecosystem services (Bayley 1995, Kingsford 2003, Fisher and Acreman 2004). The hydrology and ecology of nearly all freshwater ecosystems has been negatively impacted by physical alterations made to the riparian zone (e.g., the hardening of shorelines, the creation of locks and dams, hydroelectric power, and urban development; Benke 1990, Brown et al. 2005, Ormerod et al. 2010). This in turn, has impacted fish and wildlife populations around the world (Stein et al. 2018).

The upper Niagara River in Western New York is an example of a Great Lakes ecosystem that has been negatively impacted by urbanization for the last century. Shoreline development and industrialization occurred along the American shoreline from Lake Erie to Niagara Falls, New York, and the ecological impacts were overlooked until the 1970s. Bulkhead was installed to reduce shoreline erosion but unfortunately, degraded fish and wildlife habitat, as well (Sault et al. 1997). As the habitat decreased in the river, so did the biodiversity, which resulted in a Beneficial Use Impairment (BUI) classification in 1987. The upper Niagara River was designated an Area of Concern (AOC) by the United States Environmental Protection Agency (EPA) due to pollution, habitat degradation, and the loss of fish and wildlife populations (Great Lakes AOCs www.epa.gov). Studies have been conducted in the river to evaluate the status of fisheries, avian populations, and vegetation, however, the first ever study to evaluate the status of a freshwater turtle species was initiated in 2013 (Haas 2015).

Reptile and amphibian populations throughout the world are declining (Gibbons et al. 2000, IUCN 2009) as a result of development along shorelines, the depletion of wetlands, concentrated pollution, poaching, and collisions with boat propellers and cars. Anthropogenic development has caused the loss of nesting habitat for aquatic turtle species which necessitates longer movements and more tortuous paths from the aquatic environment to terrestrial nesting sites. Long aquatic and overland movements increase the probability of boat encounters and road mortality, respectively, as well as increasing the risk of being captured (Bulte et al. 2010, Bennett and Litzgus 2014). Habitat degradation, human disturbance, and over-harvesting are the main threats to aquatic turtle species around the world (Gibbs and Shriver 2002, Marchand and Litvaitis 2004, Aresco 2005, Federal Register 2005, Winters 2013).

Biodiversity is an important factor influencing ecosystem health and function (Dudgeon et al. 2006, Gamfeldt et al. 2008, Cleland 2011). Declines in turtle populations worldwide contributed to diversity not only in the functional groups, but in ecosystems (Gibbons et al. 2000, IUCN 2009, Buhlmann et al. 2015). Freshwater turtles have played an important role in ecosystems for millions of years. Their life-histories require aquatic and terrestrial environments, which facilitates the transfer of energy between the two (Mitchell and Buhlmann 2009). Female turtles inhabit aquatic environments to fulfill most of their life-history traits but use terrestrial habitats to deposit their eggs. Like some other organisms, turtles are both consumers and prey in the food web. Hatchling and juvenile turtles are a food source for a variety of avian predators, like bald eagle and osprey (Clark 1982, Mabie et al. 1995), mammalian predators, such as fox, raccoon, skunk, opossum, and mink, as well as predator fishes (Temple 1987, Marchand et al. 2002, Alan 2016, Avery 2018). Humans have also used turtles as a food source, threatening many species with extinction, especially in Southeast Asia (Mitchell and Buhlmann 2009). Although there are few studies showing the effects that turtles have on invertebrate communities, female Northern Map Turtles (*Graptemys geographica*) feed primarily on aquatic mussels and snails which has the potential to alter mussel communities where they forage, and ultimately the water quality. Not only are freshwater turtle species important to their ecosystems, they increase the aesthetics of their environment and are generally admired by the public.

The Northern Map Turtle is a freshwater turtle species found in the Great Lakes and surrounding waterways, as well as various drainages in the midwestern United States (Iverson 1992, Ernst et al. 1994, Conant and Collins 1998, Lindeman 2013). *Graptemys geographica* is listed as a species of least concern in the United States and Canada and can be found in great abundance throughout the Great Lakes. However, in the upper Niagara River where my study took place, the population is small and lacks recruitment (Haas 2015). Five turtles (four females and one male) were captured in one area of the river referred to as the Rich Marina Complex (RMC) located adjacent to the Black Rock Lock Canal in Buffalo, New York (Fig. 1). The individuals were initially thought to be remnants of a relict population, but their origin remains unknown due to the absence of historical data and genetic testing. Due to an extremely small population size and no evidence of local reproduction, an alternative hypothesis discussed in Haas (2015) suggested that the turtles were emigrants of Lake Erie. The turtles were monitored between 2013 and 2015 with the use of biotelemetry. Northern Map Turtles utilized some of the restored habitats in the river but spent most of their active season toward the headwaters, specifically in the RMC, where they were exposed to several threats (Haas 2015).

Several restoration projects were initiated on the upper Niagara River to create nearshore habitat with emergent vegetation, low water velocities, and restricted motorized boat access that provided fish and wildlife with suitable habitat (Mistretta 2018). Slow-current refuge habitats for fish and wildlife were created or restored in Beaver Island Lagoon (BIL), Strawberry Island Lagoon (SIL), Buckhorn Marsh, East River Marsh, Motor Island, and Frog Island (Fig. 2A-C).

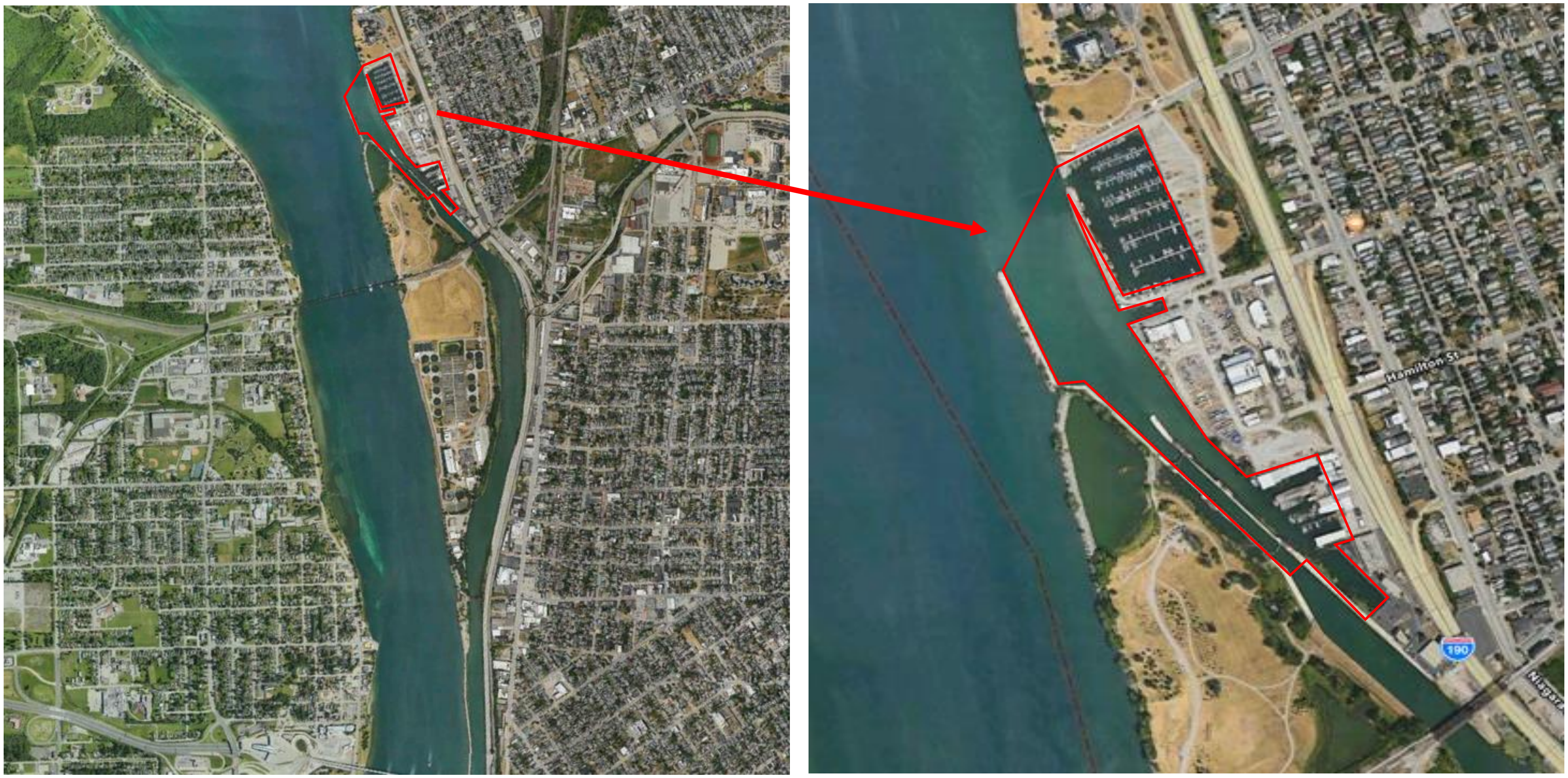

Figure 1. The headwaters of the upper Niagara River and the Black Rock Canal on the eastern shoreline. The area outlined in red represents the Rich Marine Complex (RMC) at the north end of the Black Rock Canal.

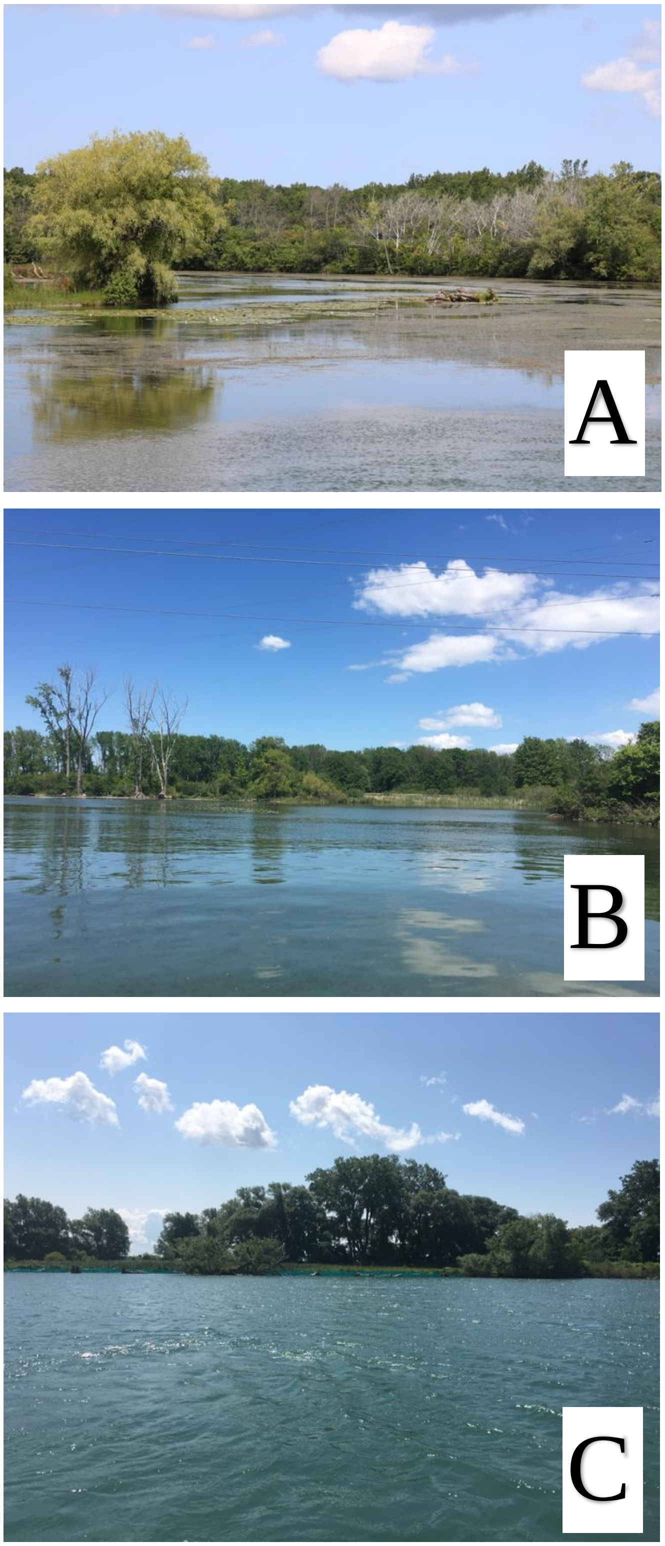

Figure 2. Restored habitats of (A) Beaver Island Lagoon, (B) Buckhorn Marsh, and (C) Strawberry Island Lagoon.

Aquatic organisms like the Northern Map Turtle may benefit from shoreline restoration in the Niagara River that reduces water current, provides basking structures, and restricts motorized boat traffic. Northern Map Turtles use nearshore habitats that provide an abundance of surface cover and deadwood snags, and where female turtles can access terrestrial habitats, specifically sandy substrates, to deposit their eggs (Lindeman 2013).

My project used a combination of conservation efforts to actively increase the population of *G. geographica* in the upper Niagara River and increase nesting site accessibility. Conservation projects with the focus on turtle populations have experimented with artificial nesting sites that increase recruitment where natural nesting sites are lacking (Buhlmann and Osborne 2011, Paterson et al. 2013, Wnek et al. 2013, Avery 2018). The effectiveness of an artificial site is generally evaluated by the total number of turtles that encounter the site and the number of nests that are laid. The hatching success, health of hatchlings, incubation conditions, and emergence dates are compared between artificial sites and natural sites to further evaluate the effectiveness. Floating nesting platforms have been created for black terns and loons, but never turtles (Shealer et al. 2006, Piper et al. 2002). However, for the purpose of turtle nesting habitat, they may reduce threats from mammalian predation, human disturbance, and long overland movements required by female turtles looking for nesting sites (Gibbs and Shriver 2002, Moore and Seigel 2006, Wnek et al. 2013). To mitigate lack of nesting sites in the upper Niagara River, I supplemented nesting habitat with three floating, artificial nesting platforms in 2016.

The second portion of my project was a translocation of ten *G. geographica* from Lake Erie into the river to increase the population and simulate an expedited rate of immigration. The translocation of turtles from one location to another is an alternative conservation technique used to augment small populations of turtles (Burke 1991, Ashton and Burke 2007, Tuberville et al. 2008, Germano and Bishop 2009, Attum et al. 2013). Traill et al. (2007) estimated that the minimum viable population (MVP) necessary for a reptile or amphibian population to persist is nearly 4,000 individuals, but warned that the context-specific nature of this type of analysis results in large variance. Shoemaker et al. (2013) found that populations with as few as 15 female bog turtles (*Glyptemys muhlenbergii*) could persist for at least a century because of their life-histories and argued that small populations of long-lived species are worth conservation efforts. The population of *G. geographica* in the upper Niagara River consisted of four individuals at the start of my study and although the variables that influence MVP were not evaluated, there was enough evidence to support a supplementation and continued monitoring of the population.

Northern Map Turtles exhibit extreme site fidelity to basking, nesting, and overwintering sites (Lindeman 2013, Haas 2015). This innate behavior to occupy familiar locations causes some turtles to exhibit homing behavior after they are relocated. Translocated individuals will often immediately disperse from their release site and show significant movement within the first few weeks of the translocation followed by a stabilization in movement patterns (Lebboroni and Chelazzi 2000, Tuberville 2008, Germano and Bishop 2009). The effectiveness of a translocation can be evaluated by comparing translocated and resident movements. The translocation can be considered successful when translocated individuals' exhibit similar movements to resident individuals, exhibit site fidelity to their release site, and produce offspring (Tuberville et al. 2005, Attum et al. 2013, Attum and Cutshall 2015). However, it can be difficult to associate movements with specific behaviors due to physical boundaries that restrict homing movement, and individuality in movement patterns.

One goal of my study was to investigate whether emigrant turtles from Lake Erie, unfamiliar with the upper Niagara River, would exhibit homing behavior, or utilize restored habitats in the river. Another goal of the study was to determine which habitats in the upper Niagara River are suitable for the future construction of permanent nesting sites with consideration for habitat use and the use of artificial nesting sites. With these main goals in mind, I generated the following study questions.

Study Questions

1. Do the translocated Northern Map Turtles exhibit site fidelity or homing behavior?

2. What are the total distances moved by translocated and resident Northern Map Turtles in the active seasons of 2017 and 2018? Is there a difference in the total distance moved by translocated turtles between multiple years?

3. Do the translocated and resident turtles have similar home ranges and do they use similar swimming paths when moving in the river?

4. Do the translocated turtles initiate brumation at similar times and locations compared to the resident individuals, and do the turtles exhibit hibernaculum site fidelity?

5. Do the resident and translocated turtles use the basking/nesting platforms?

Materials and Methods

Study Species:

Graptemys geographica are found in large rivers and lakes (Gibbs et al. 2007, Lindeman 2013) and can be identified by a yellow, triangular spot located behind each eye, as well as a keeled carapace and flared posterior scutes. The species exhibits extreme sexual dimorphism where females can display carapace lengths from 18 to 27 cm, and males 9 to 16 cm (Gibbs et al. 2007; Fig. 3). Female *G. geographica* are molluscivores, primarily feeding on the zebra and quagga mussels (invasive species in the Great Lakes), snails, and Trichoptera larvae. Freshwater mussels make up 94.8% of the adult female map turtle diet on average (Lindeman and Sharkey 2001, Lindeman 2006), while insectivorous males have a strong preference for Trichoptera larvae (Lindeman 2006, Bulté et al. 2008).

At the northeastern part of their range, *Graptemys geographica* have an active season from mid-April to early November. They prefer habitats with low flow and silty substrate, an abundance of food, and structures for basking (Gibbs et al. 2007, Lindeman 2013, Haas 2015). Basking is essential to map turtle physiology for several reasons. Turtles are ectotherms and maintain their optimal body temperature by using solar radiation and conduction. Basking strengthens and dries the shell and skin providing protection from ectoparasites and fungal infections (Boyer 1965, Ryan and Lambert 2005). Basking also assists in metabolic processes. Hammond et al. (1988) found that fed turtles basked significantly more than non-fed conspecifics.

Graptemys geographica tend to bask in groups and are quick to retreat into the water at any signs of disturbance (Ernst et al. 1994, Lindeman 2013). In Mississippi, Yellow-Blotched Map Turtles (*Graptemys flavimaculata*) retreated into the water when 65 out of 119 boats passed

(Moore and Seigel 2006). *Graptemys flavimaculata* basked significantly less at a disturbed site compared to an undisturbed site, which ultimately caused physiological repercussions. At the disturbed site, turtles had a significantly higher ratio of heterophil:lymphocyte, which is a reliable indicator of stress, and condition was significantly poorer (Selman et al. 2013).

During their inactive season, *G. geographica* are submerged for nearly six months and remain aerobic. This requires a well-oxygenated hibernaculum to allow oxygen exchange through cloacal or cutaneous respiration, rather than inhaling air into the lungs. They exhibit decreased heart and metabolic rates to limit their energy use and their need for oxygen, however, they are still alert and can move lethargically (Crocker et al. 2000, Reese et al. 2001). The availability of suitable overwintering sites and the ability of the turtles to find these habitats, may be a determining factor in their distribution.

River shorelines and large lakes have ideal water current velocity and dissolved oxygen concentrations for aquatic turtles to survive through the winter months (Gibbs et al. 2007, Jackson et al. 2007). *Graptemys geographica* are known to overwinter in a communal hibernaculum (Vogt 1980a, Pluto and Bellis 1988, Ultsch et al. 2000, Carrière et al. 2009, Richards-Dimitrie 2011). However, in the upper Niagara River, turtles migrate to individual hibernacula in separate branches of the river (Haas 2015).

Female Northern Map Turtles reach sexual maturity around ten years of age, while males reach maturity anywhere from four to six years of age (Lindeman 2013). Females lay one to three clutches per year between May and July (Lindeman 2013, Nagle and Congdon 2016), and each clutch generally contains 10 to 12 eggs (Conant et al. 1998, Jensen et al. 2008, Buhlmann et al. 2009). In the upper Niagara River, Haas (2015) reported a Northern Map Turtle nest containing 21 eggs.

Figure 3. Two similarly aged, adult Northern Map Turtles exhibiting sexual dimorphism (male on the left and female on the right).

Study Sites:

Presque Isle State Park, Lake Erie

Translocated *G. geographica* were captured from Presque Isle State Park in Erie, Pennsylvania by Dr. Peter Lindeman. The park is an extensive network of wetlands located on the shoreline of Lake Erie. The Presque Isle Bay backwaters include Graveyard Pond and Misery Bay, where the translocated turtles were captured. The population consists of more than 1,000 *G. geographica* that have been marked over the past 19 years (Lindeman 2013). Graveyard Pond is classified as a Palustrine wetland with an area of less than 8.1 hectares and a water depth of less than 2 meters. There is less than 30% vegetation cover and the substrate is partially sand and mud. The water regime is permanently flooded (Wetland Mapper 2015).

The upper Niagara River

The Niagara River is nearly 60 km long and flows northwest from Lake Erie to Lake Ontario which makes it a strait rather than a true river. The upper Niagara River, located above Niagara Falls splits into two branches around Grand Island, has very little tortuosity, and areas of very strong water current. The backwater habitats located within the river relevant to my study include Strawberry, Frog, and Motor Islands, East River and Buckhorn Marshes, Beaver Island Lagoon, and the RMC.

Beaver Island Lagoon is a wetland habitat located in Beaver Island State Park on the west branch of the upper Niagara River. The habitat is like Presque Isle Bay wetlands in that the habitat remains permanently flooded and has silty substrates. However, BIL is less extensive, has slow moving water, and is shallower in most areas. Floating logs and surface cover provide basking opportunities and refuge for freshwater turtles in BIL, and quagga and zebra mussels are very abundant. Common Snapping Turtles (*Chelydra serpentina*), Red-Eared Sliders (*Trachemys scripta elegans)*, and Northern Map Turtles have all been observed in the lagoon (Haas 2015).

Another important site in the upper Niagara River is the RMC, adjacent to the Black Rock Lock in Buffalo, New York. Resident *G. geographica* spent nearly every day in the RMC during the active seasons of 2013 and 2014 (Haas 2015). This site has an average depth of four meters, no water current, and an abundance of food and basking structures for parts of the turtles' active season. The RMC has 1,761 meters of shoreline and of that, only 16 meters remain unobstructed. There are two marinas that facilitate boat traffic, and the area is adjacent to a boatyard where the substrate is potentially unsuitable for turtle nesting. However, the site has a large area with restricted boat access and driftwood occasionally offers basking opportunity.

Capture Methods:

The turtles monitored in the upper Niagara River were hand-captured and passively trapped. Basking trap frames were 1.2 meter^2 and made from PVC pipe (10 cm diameter) and snow fencing. Basking traps are effective in capturing aquatic turtle species that bask frequently. The trapping of translocated turtles from Presque Isle was conducted using basking traps as well as fyke nets, another passive trapping method (Lindeman 2013). Floating cushions were placed in the cylindrical nets to prevent freshwater turtle species from drowning (personal communication with Peter Lindeman). Twelve adult (six females and six males) *G. geographica* were captured from Presque Isle.

I recaptured turtles periodically to download data from the archival loggers and to record body mass, carapace length, and plastron length. I also noted the presence of ectoparasites and any unusual features. I measured carapace and straight plastron lengths using a digital caliper and measured mass with a digital scale. Tail length and cloacal position were used to determine sex (Cagle 1954) and the Sexton (1959) method of counting shell annuli to determine the age was used when annuli were visible. A parallel study examined the growth rates and body conditions of the translocated turtles (Karcher 2019).

At the end of the active season, equipment replacements were required to assure transmitter contact over winter. However, I was unable to snorkel for turtles in the RMC, and floating and submerged debris made it difficult to capture individuals with a long net. I was not permitted to deploy basking traps in the marina during my study, which decreased the capture rate compared to the active seasons of 2013 through 2015 when basking traps were deployed. Turtles were released within 24 hours of their time of capture and released at the exact locations where they had been captured. When the equipment did not need to be replaced, captured turtles were released immediately after processing.

Biotelemetry Techniques:

Biotelemetry has been used extensively and effectively to track animals in their natural habitats. Studying an animal in their habitat allows researchers to investigate behavior, habitat use and overall ecology with minimal disturbance (Cooke et al. 2004). Analyzing home ranges, movements, and behavior allows wildlife management to evaluate the status of populations and make educated decisions regarding the conservation of species.

Active and passive biotelemetry techniques were used to locate turtles in my study. The turtles were located nearly every day from a boat and GPS coordinates were taken using a GPS unit (Magellan handheld eXplorist). The general location of a turtle was found first by using radio telemetry. Resident (n= 7) and translocated turtles (n= 10) were outfitted with a radio and sonic transmitter along with an archival depth and temperature data logger (Fig. 4). Smaller radio and sonic transmitters (Radio: Holohil Systems Ltd., 2B-2F, 165 MHz, mass 6g, length 20.5mm, width 9.0mm, and depth 9.5mm, Sonic: Sonotronics, IBT-96-5E, mass 7.8g, length 36.5mm, and diameter 12.7mm) were attached to smaller turtles (males) to ensure the mass of the equipment was <5% of the turtles' body mass. Larger radio and sonic transmitters (Radio: Lotek Wireless Inc., two-stage VHF harness temperature transmitter, 164 MHz, mass 18.5 g, length 30.5 mm, width 26.4 mm, and depth 11.2 mm, Sonic: Sonotronics, IBT-96-9E, mass 9.1 g, length 49.6 mm, and diameter 11.4 mm) were attached to larger turtles (females). Transmitters and dataloggers (Onset DST milli L-F temp-depth with a memory capable of recording 699,000 measurements) were attached to the carapace by drilling 2.8mm diameter holes into the turtles' marginal scutes, feeding steel leaders through, and looping them back through the eyelets of the transmitter. PC-7 marine epoxy secured the equipment to the carapace and was molded to create a more hydrodynamic shape. The larger radio transmitters and all the sonic transmitters had a phone number printed on them so that the general public could report a capture. After epoxying the equipment, the turtles were kept overnight to allow the epoxy to cure. Transmitters had a battery life of 5 to 8 months, so turtles were trapped periodically to replace equipment and download temperature and depth measurements. A Communications Specialists portable receiver (R-1000) was attached to a handheld Telonics H-antenna (RA-23k) and used for scanning shorelines at closer ranges. To locate a turtle at greater distances, a six-element Yagi antenna (Arcadian Inc.) was attached to the receiver in place of the handheld antenna (Fig. 5) and mounted on the boat, or in poor weather, the bed of a truck. Once the general location of a turtle was known, sonic telemetry allowed me to find a more exact location. Sonic telemetry was conducted using a VH110 hydrophone (Vemco) connected to a VR100 topside receiver (Vemco). If the turtle was basking, I used binoculars or a 75-300 mm telephoto zoom lens to photograph and identify individual turtles. Occasionally after a turtle was outfitted and released, the frequency of its radio transmitter would stray from the frequency that the manufacturer reported. Throughout the study, when I lost contact with a transmitter, I scanned several radio frequencies that were in proximity to the listed frequency.

Passive radio and sonic telemetry were also used but found to be less useful. Radio receiver stations and nine-element Yagi antennas (Arcadian Inc.) were deployed on Motor Island and at the Great Lakes Field Station that continuously scanned for discrete radio frequencies and recorded the date and time when a frequency was detected. There were no records on the radio receiver placed at the Great Lakes Field Station, perhaps because the turtles were traveling up the canal, close to the shoreline, and the antenna was focused beyond them. Passive sonic telemetry was conducted using submersible ultrasonic receivers (SURs), which are used to passively track aquatic species that are tagged with sonic transmitters. The transmitters each have a specific frequency that makes it possible to identify individual animals. The receivers continuously interrogate the water for discrete sonic frequencies and when a frequency is detected, a record is saved with a date and time stamp. During the first field season, I deployed SURs near the basking/nesting platforms to detect turtle presence. The two habitats where the platforms were deployed both had small enough areas that when turtles were located within these habitats, the SURs detected them for the entirety of their stay. Therefore, the SURs were unnecessary. SURs were also deployed at forks in the river when I was unable to locate a turtle using active tracking.

When a turtle was located, several environmental variables were measured for a parallel study that analyzed basking behavior in response to wind speed. Wind speed was measured using an anemometer (handheld Kestrel 3000). Water current speed was measured at turtle locations and at transects in the river using a Global Water FP211 Flow Probe. These data were used to create "least-costly paths" in Geographical Information Systems (GIS). I used a sonar depth finder (Lowrance) to determine the water depth at turtle locations, and distance from shore was measured using a waterproof infrared range finder (Nikon PROSTAFF). Water temperatures were measured using a Fluke 51 II digital thermometer. I used water temperature and photoperiod (day of the year) to determine the cue hierarchy of factors that affect the length of individual turtles' active seasons.

Tracking during winter was conducted from shore once every week and turtle locations were calculated using the triangulation method. Two GPS coordinates were taken from shore as far apart as possible and the bearings towards the loudest radio signal were recorded. I then used a program to calculate the GPS coordinates where the bearings intersected (http://geo.javawa.nl/coordcalc/index_en.html).

In the spring of 2018, an underwater drone (Trident OpenROV; Fig. 6) was used to observe two turtles in their hibernacula. When working with aquatic organisms, biotelemetry allows researchers to get within approximately 5 meters of the tracked organism without knowing its exact location until obtaining a visual. Biotelemetry, in tandem with the underwater drone, allowed me to visualize hibernacula in areas that I could not have observed otherwise (i.e., the ACE and New York State Power Authority peninsula). One turtle was video recorded emerging from her hibernaculum. The drone was used during the active season to observe turtles in the RMC, but only until the emergent vegetation interfered with drone movement.

Figure 4. Female *G. geographica* individual with radio and sonic transmitters and an archival temperature-depth data logger attached to her carapace.

Figure 5. Six-element Yagi antenna used in active and passive radio telemetry.

Figure 6. Underwater drone used to observe submerged turtles in their hibernacula.

Translocation Techniques:

The translocated turtles were held in captivity for an extensive five-month quarantine required by the New York State Department of Environmental Conservation. They were physically examined for leeches, which are common parasites to freshwater turtle species and are usually visible if present. Two leeches were found and removed from two female turtles. Oral and cloacal swabs were taken, sent to the Cornell University's Wildlife Epidemiology Laboratory, and tested for Ranavirus, Mycoplasma species, Herpes, and Adenovirus (Table 1). One male turtle tested positive for the ubiquitous Adenovirus. As a precaution, we returned him to Graveyard Pond. The rest of the translocated turtles were outfitted with transmitters and data loggers and released into the upper Niagara River 10 meters off the west shore of Grand Island during the last week of October and the first week of November 2016. After their release, the translocated turtles were tracked nearly every day and their movements were analyzed. One of the translocated males that was released into the upper Niagara River was observed having a difficult time swimming. I recaptured him and brought him back to the laboratory to remove some of the epoxy from his carapace. The following day when I returned to his tank to re-release him, he had died overnight. I suspected that the stress of the extended quarantine, the release late in the season, the recapture, and the changes in water temperature from the lab to the river and back to the lab caused his death.

Table 1. Disease and virus test results from the Wildlife Epidemiology Laboratory submitted by Cornell University.

Wildlife Epidemiology Laboratory
Matt Allender, DVM, MS, PhD, Dipl. ACZM
2001 S. Lincoln Ave., Urbana, IL 61802
217-265-0320; mattallender@vetmed.illinois.edu

Submitting Insitution:
Cornell University

Disease Investigation:

ID1	ID2	ID3	Sample Type	FV3 (Ranavirus)	*Mycoplasma* sp.	Herpes Consensus PCR	Adenovirus Consensus PCR
NY 102590 1	14656 1-16-1-1	XA	Oral Swab DNA	Neg	Neg	Neg	Neg
NY 102590 1	14656 1-16-1-1	XA	Cloacal Swab DNA	Neg	Neg	Neg	Neg
NY 102590 2	14656 1-16-2-1	XB	Cloacal/Oral Swab DNA	Neg	Neg	Neg	Neg
NY 102590 3	14656 1-16-3-1	XC	Cloacal/Oral Swab DNA	Neg	Neg	Neg	Neg
NY 102590 4	14656 1-16-4-1	XH	Cloacal/Oral Swab DNA	Neg	Neg	Neg	Neg
NY 102590 5	14656 1-16-5-1	XI	Cloacal Swab DNA	Neg	Neg	Neg	Neg
NY 102590 6	14656 1-16-6-1	XJ	Cloacal/Oral Swab DNA	Neg	Neg	Neg	Neg
NY 102590 7	14656 1-16-7-1	MA	Cloacal Swab DNA	Neg	Neg	Neg	Positive
NY 102590 8	14656 1-16-8-1	MB	Cloacal Swab DNA	Neg	Neg	Neg	Neg
NY 102590 9	14656 1-16-9-1	MC	Cloacal Swab DNA	Neg	Neg	Neg	Neg*
NY 102590 10	14656 1-16-10-1	MH	Oral Swab DNA	Neg	Neg	Neg	Neg
NY 102590 10	14656 1-16-10-1	MH	Cloacal Swab DNA	Neg	Neg	Neg	Neg
NY 102590 11	14656 1-16-11-1	MI	Cloacal Swab DNA	Neg	Neg	Neg	Neg
NY 102590 12	14656 1-16-12-1	MJ	Cloacal Swab DNA	Neg	Neg	Neg	Neg

Interpretation

Most turtles were negative for common upper respiratory pathogens. However, a single animal was positive for adenovirus on cloacal swab. Adenovirus can cause both respiratory and gastrointestinal disease, but may also be a subclinical inhabitant. The adenovirus was sequenced as 96% homologous to an adenovirus detected in a yellow-bellied slider and 95% homologous to a sequence in a red-eared slider. There was a second animal (MC) that had a positive band, but when sequenced was determined to be host genome and not an adenovirus. Herpesvirus and Mycoplasma are ubiquitous in many free-ranging turtle populations, but detection can vary between seasons and years. Thus, a negative result at this point in time, does not confirm that the animal does not have the pathogen and the ability to shed at a future date. If you have any questions or would like to discuss further, don't hesitate to call.

Basking/Nesting Platforms:

Three artificial basking/nesting platforms were designed, constructed, and deployed in the upper Niagara River (Fig. 7 and 8). Two were deployed in BIL on opposite shorelines (Fig. 9) and one was deployed in the ACE. The nesting sites were built atop floating docks made from recycled plastic (purchased from EZ docks), had an area of 5.6 $meters^2$, and had two floating ramps on the sides of the dock that provided basking structure and access to the nesting substrate. There were 30-degree ramps that began at one end of the platform and led to a wooden sandbox structure built one meter above the dock. Half of the ramp was filled with sand and the other half was plywood covered in sand-colored outdoor carpeting. The wooden sandboxes were filled with 15 centimeters of masonry sand which is suitable substrate for nesting turtles. Other *Graptemys* species like the Yellow-blotched map turtle lay nests that are on average 9 centimeters in depth (Horne et al. 2003). The *G. geographica* nest found in Rich Marina boatyard in 2014 was 15 centimeters deep (Haas 2015) and according to the literature, the depth of the nest was greater than the average found in other sites (Horne et al. 2003, Baker et al. 2010, Nagle and Congdon 2016). Clear, monofilament line was suspended above the substrate to reduce the risk of avian interference or predation and above the floating access ramps to deter waterfowl. Shealer et al. (2006) suggested a drainage system for the sand substrate and a mechanism to withstand changing water levels. Holes were drilled in the bottom of the wooden box structure and covered with mesh to facilitate water drainage but restrict the movement of sand. To account for changing water levels, the platforms in BIL were held down by 5 meters of rope and fluke anchors attached to each corner of the platforms. In the ACE, the platform was attached to the bulkhead with chain inside a PVC tube to keep the platform from hitting the bulkhead, while also compensating for changing water levels (Fig. 10). A surveillance camera

(HCO Spartan GoCam) capable of live feed video was mounted above each of the platforms using a 3-meter-tall PVC pipe and angled down toward the substrate. The camera sent pictures to my email at intervals of three minutes. This allowed for a constant monitoring of the platforms to record any basking or nesting activity. When a turtle was seen emerging onto the nesting substrate, I changed the camera mode to video recording. All photographs were saved to the camera's memory card.

If a nest was dug and eggs were laid on a platform, a protocol was established. We planned on excavating the first nests and incubating them in a chamber at Buffalo State College. *Graptemys geographica*, like most species of turtles, exhibit temperature-dependent sex determination (Vogt and Bull 1984, Standora and Spotila 1985, Spotila et al. 1987). Any nest with a temperature above 31°C produces female hatchlings and nests at 25°C or cooler produce mostly or all males. The population dynamics in the upper Niagara River are complex and would require further analysis of the variables that have influenced the historical sex ratio for this specific population. Mark-recapture studies allow researchers to study survivorship and the demographics of a population over time. Northern Map Turtle hatchlings would have been tagged with visible implant elastomers (VIE). This technique has been used on small reptiles to avoid the traditional notching method (Anderson et al. 2015). Juvenile aquatic turtles have fontanelles, or spaces on the marginal scutes, that fill in as the animal grows, analogous to "soft spots" on a baby's skull. As the fontanelles grow, the notches fill, making it difficult to identify the individual in later years for mark-recapture studies.

Although there was no nesting activity, the Aquarium of Niagara had agreed to house any hatchlings for a one-year head-start program. Hatchlings are highly susceptible to predation because of their extremely small size (Britson and Gutzke 1993). Head-start programs increase the probability of survival by allowing hatchlings to exhibit body growth before they are released into a natural habitat and exposed to predators. Hatchlings of some turtle species remain in the nest overwinter until the following spring to avoid anoxic conditions overwinter (Ultsch 1989). It has been suggested that this is a strategy to avoid the harsh conditions of winter by emerging in the spring when conditions are more favorable for faster growth rates (Chessman 2018). After the one-year head-start program, the hatchlings were to have been released into Beaver Island Lagoon.

Figure 7. Floating basking/nesting platform in the building process.

Figure 8. Floating basking/nesting platform design with surveillance camera mounted above.

Figure 9. Two basking/nesting platforms deployed in Beaver Island Lagoon on Grand Island, New York.

Figure 10. Basking/nesting platform deployed in the ACE and a hinge device that accommodated changing water levels.

Data Analysis

Turtle Movements:

To calculate the mean straight-line distance moved per day, I measured the distance between two consecutive turtle locations and divided that length by the amount of time between readings. In cases when the turtle's path crossed land, I created a more biologically realistic path completely through the aquatic environment.

Turtles were not observed all day, so the average daily distance moved while located in a backwater habitat was difficult to calculate accurately. When a turtle was in the same backwater habitat for multiple consecutive days, the same GPS coordinates were recorded, and an average distance moved was calculated later depending on the length of the backwater area (Table 2). I measured the total length of the habitat, divided the distance in half, and used that value as the average daily distance moved, like the methods used by Haas (2015).

I defined the active seasons as 1 April to 30 November based on the first and last month that turtles became active and inactive, respectively. Translocated and resident turtles exhibited relatively large differences in dates of activity and inactivity. Therefore, I separated the active season into three seasons; "spring" (1 April to 31 May), "summer" (1 June to 30 September), and "fall" (1 October to 30 November) for all data analyses.

Turtle Swimming Paths:

Northern Map Turtles are known to avoid high currents (Ernst et al. 1994) and resident turtles in the upper Niagara River spent nearly their entire active season in an area with minimal water current (Haas 2015). I hypothesized that water current in the river, specifically at the headwaters, was a factor that heavily influences turtle swimming paths. To test this hypothesis, I used a least-cost model (Adriaensen et al. 2003) which allowed me to model the most efficient paths for turtles to use when swimming upriver. Desrochers et al. (2011) analyzed the cost of avian homing movements by using similar toolkits. I used several spatial analysis tools in Geographic Information Systems (ArcGIS 10.5.1) to create hypothetical swimming paths. This method of modeling was also used by Ferreras (2001) to analyze the cost associated with habitat fragmentation on populations of the Iberian lynx (*Lynx pardinus*).

I took 50 measurements for water current speed along transects in the upper Niagara River headwaters. I sampled at a constant depth of 0.5 meters below the surface. When I observed turtles swimming in the river, they were located at approximately 0.5 meters below the surface, therefore, flow measurements were taken at that depth. Water current data were entered into Geographic Information Systems (ArcGIS 10.5.1). Northern Map Turtles exhibit minimal terrestrial movements, therefore, I created barrier polylines to exclude overland movements, as well as lines that striated the river. This allowed me to interpolate water current speed along the shorelines separately from the center of the river.

The "Inverse Distance Weighted (IDW)" tool in Spatial Analyst is commonly used to interpolate within a surface layer. This tool creates values at un-sampled sites located between sample sites where the characteristic was measured (Stashelek and Madden 2015, Pande and Moharir 2018). I used IDW to interpolate water current speeds across the surface of the river. I measured water current speed at transects across the river and interpolated the water speed across locations that were not sampled, within each of the striations. I then used the "Plus" tool in Spatial Analyst to merge the interpolated sections. Turtle locations were entered into ArcGIS and using the "Central Feature" tool in Spatial Statistics, turtle locations in high densities were clustered to create termini for swimming paths. I used the "Cost-Distance" tool in Spatial Analyst and assigned higher (energetic) costs to higher water current speeds. Swimming paths were then generated between clusters using the "Least-Cost" tool to model the least energetically expensive path for turtles swimming upriver.

Brumation:

At the beginning and end of every active season (April 1st – November 30th), I recorded the date that turtles became active and inactive, respectively. I recorded the date that a turtle was located >10 meters from its hibernacula and considered it the date they became active. I recorded the date they became inactive as the last date that they made a movement >10 meters. The location following their final movement was deemed their hibernaculum. An underwater drone that was acquired in 2018 allowed me to view hibernacula in the spring and fall of that year. For each hibernaculum, the water depth, distance from shore, and water temperature were recorded.

Basking:

Surveillance cameras mounted on each platform took a photograph every three minutes and recorded them on a memory card. While filtering through the photographs, I recorded the date, time, and duration of each basking event for each tracked turtle that was observed basking on the platform. I also recorded the total time that platforms were monitored, and the total time individual turtles were in the same habitat as the platforms. This allowed me to calculate a basking time budget. The camera batteries were changed approximately once a week and during those occurrences, I subtracted 10 minutes from the total time photographed to account for the disturbance. For each tracked turtle that was observed basking on a platform, I calculated the average number of basking events per day (frequency), the average duration of an event, and the total time spent basking. I compared basking behavior on the platforms between resident and translocated turtles when they were in the same habitat at the same time. I also compared basking behavior of individual turtles between years when it was possible.

Table 2. Important backwater habitats, their GPS coordinates, the total length of the habitat, and calculated mean daily distances moved by the turtles using those habitats.

Habitat	Latitude	Longitude	Habitat Length (meters)	Distance Moved (meters)
ACE Boat-slip	42.933010	-78.903472	120	60
Beaver Island Lagoon	42.961815	-78.959201	520	260
Big Six Mile Creek	43.021498	-79.009965	528	264
Broderick Bridge	42.915057	-78.903266	44	22
Buckhorn Marsh	43.062912	-78.999196	464	232
Canal in the RMC	42.934930	-78.905986	316	158
Cove, Black Rock Canal	42.931258	-78.901150	60	30
Miller Creek, Canada	42.951430	-78.976480	348	174
NYSPA Peninsula Cove	43.066060	-79.002248	310	155
Rich Marina	42.939708	-78.907668	246	123
Strawberry Island Lagoon	42.954970	-78.922631	410	205
West Marina	42.943215	-78.909319	162	81

Results

There were 17 Northern Map Turtles tracked throughout the study and over 1,230 observations made (Table 3).

1. *Do translocated turtles exhibit site fidelity or homing behavior?*

Northern Map Turtles were released into the upper Niagara River in late October and early November. Immediately after the turtles were released, they moved inshore toward backwater habitats in Beaver Island Lagoon. During the fall of their release, three females (TF4, TF5, and TF6) moved nearly double the distance they had moved during the same time the following year (Fig. 11).

Throughout the study, the translocated individuals exhibited site fidelity to the upper Niagara River with two exceptions and exhibited extensive home ranges and movements compared to resident individuals. The translocated turtles exhibited extensive ranges, utilizing the Canadian shoreline, the entire Grand Island shoreline, and an area south of the Niagara River (Fig. 12), whereas resident turtles were only located at the southern end of Grand Island, never utilized the Canadian shoreline, and spent most of their time in one habitat toward the headwaters (Fig. 13). One resident turtle (RF4) that was newly captured in 2016 was displaced and exhibited a range more like translocated turtles than other residents. When both resident and translocated turtles were in the river they remained along shorelines and exhibited long and straight movements, parallel to the flow of the river.

Table 3. Turtles monitored throughout the study.

Turtle ID	Original Capture Location	Sex	Number of Observations	Dates Monitored
RM1	Niagara River	M	126	April 2016 - June 2017
RM2	Niagara River	M	29	November 2016 - April 2017**
RM3	Niagara River	M	23	September 2016 - April 2017**
RF1	Niagara River	F	260	April 2016 - November 2018
RF2	Niagara River	F	111	April 2016 - June 2017*
RF3	Niagara River	F	6	August 2017 - August 2017*
RF4	Niagara River	F	128	May 2016 - November 2018
Total			**683**	
TM1	Lake Erie	M	38	October 2016 - April 2017**
TM2	Lake Erie	M	11	October 2016 - November 2016*
TM3	Lake Erie	M	37	October 2016 - December 2017*
TM4	Lake Erie	M	45	October 2016 - April 2017**
TF1	Lake Erie	F	16	October 2016 - April 2017**
TF2	Lake Erie	F	5	October 2016 - November 2016*
TF3	Lake Erie	F	75	October 2016 - August 2017**
TF4	Lake Erie	F	139	October 2016 - April 2018**
TF5	Lake Erie	F	181	October 2016 - June 2018*
TF6	Lake Erie	F	235	October 2016 - November 2018
Total			**547**	

* Lost contact with transmitter
** Mortality

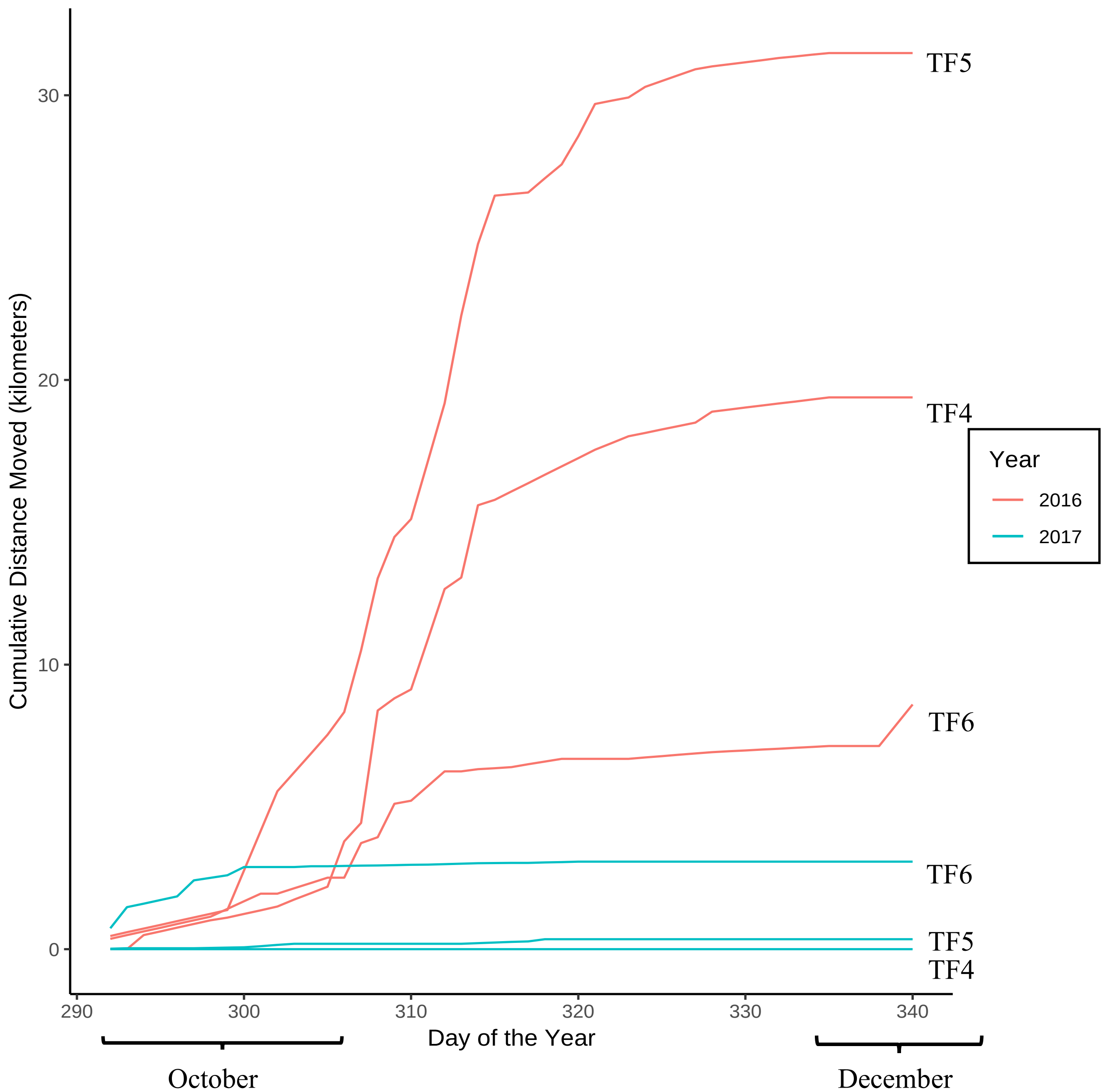

Figure 11. Total distance moved by translocated turtles in the fall of 2016 and 2017.

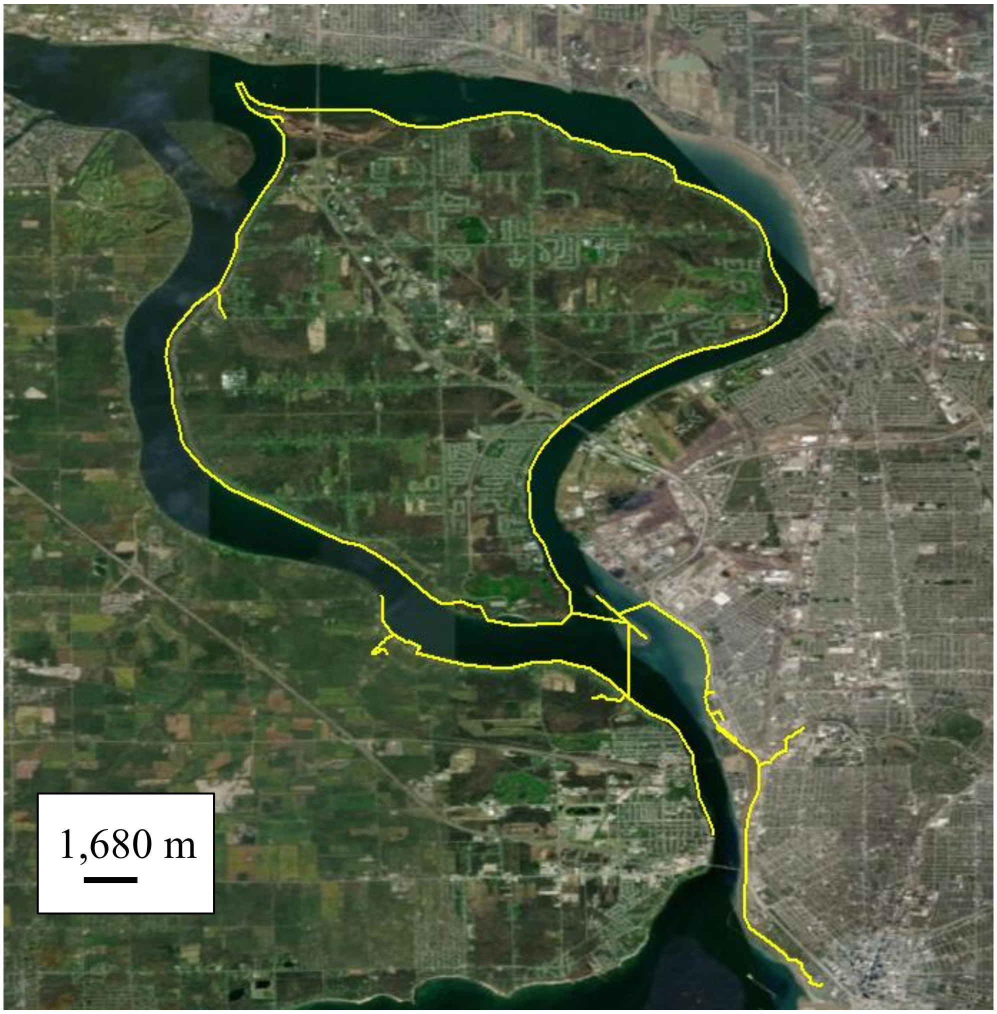

Figure 12. Combined home range of translocated Northern Map Turtles (n=4). Note the use of the entire shoreline of Grand Island, the Canadian shoreline including two creeks that run in the direction of Presque Isle State Park, and Erie Basin Marina located on the shoreline of Lake Erie.

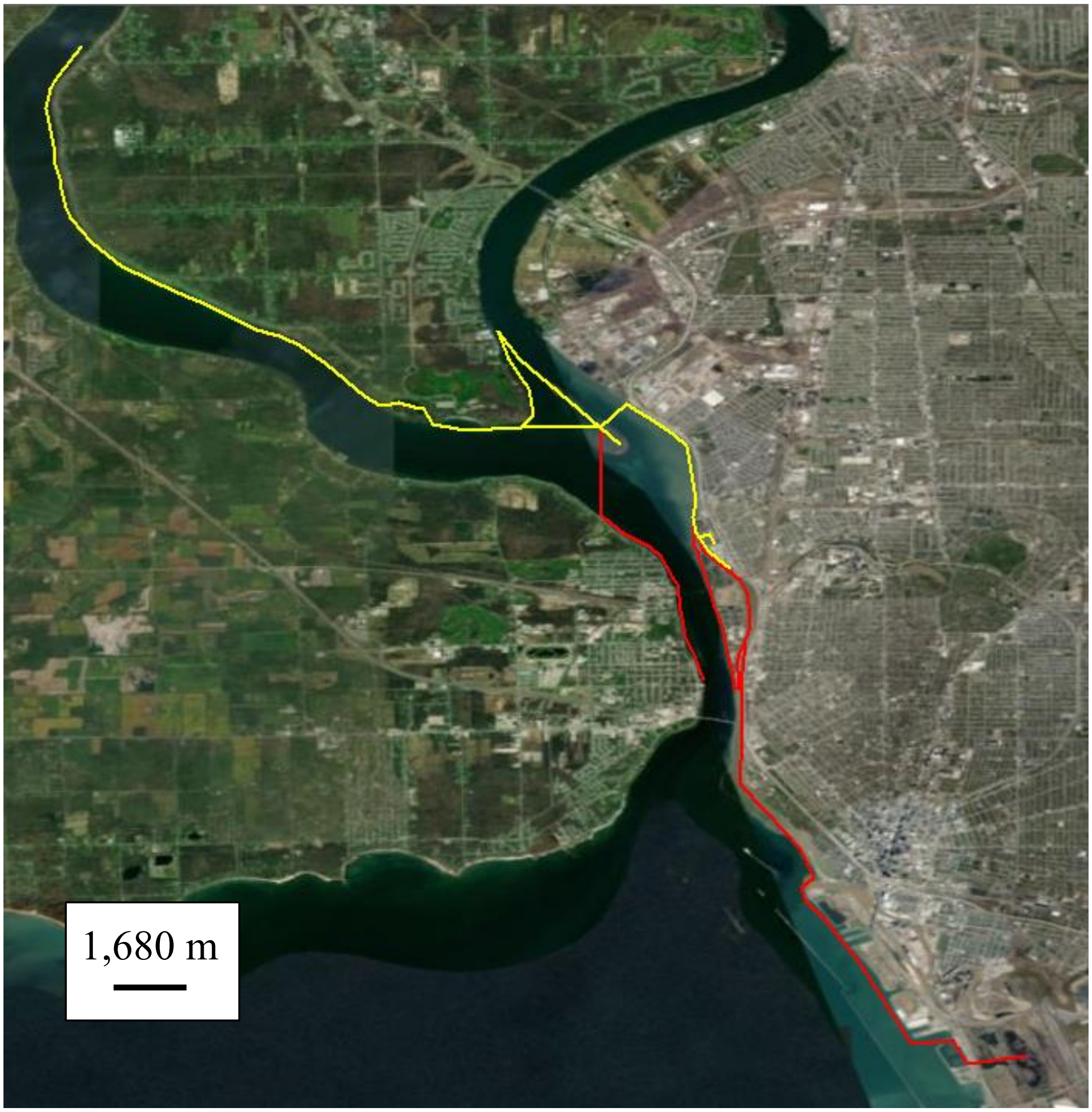

Figure 13. Combined home range of resident Northern Map Turtles (n=4). The red line represents the movements of resident female (RF4) after an anthropogenic displacement.

2. *What are the total distances moved by translocated and resident Northern Map Turtles in the active season of 2017 and 2018? Is there a difference in the total distance moved by translocated turtles between multiple years?*

There was a clear difference between the total distances moved by resident and translocated turtles (Fig. 14). In 2017, the translocated turtles moved between a total of 40 and 120 kilometers during each of the active seasons of 2017 and 2018, while residents moved less than 30 kilometers in any given season (Table 4). Resident turtles showed similar lengths of movements every year that they were tracked, spending most of their time in the RMC and making recurring movements between summer and winter habitats.

During the summer of 2017, translocated females (TF3, TF4, TF5, and TF6) each moved at least double the distance that resident females (RF1 and RF4) moved. Translocated female (TF5) moved ten times the distance moved by resident female (RF1).

One translocated female (TF6) that was tracked consistently through 2018 exhibited nearly the same total distance moved in 2018 as in 2017 but moved an additional 5 kilometers during her second year in the river. The translocated female was in the RMC at the end of the active season within 5 meters of a resident female (RF1).

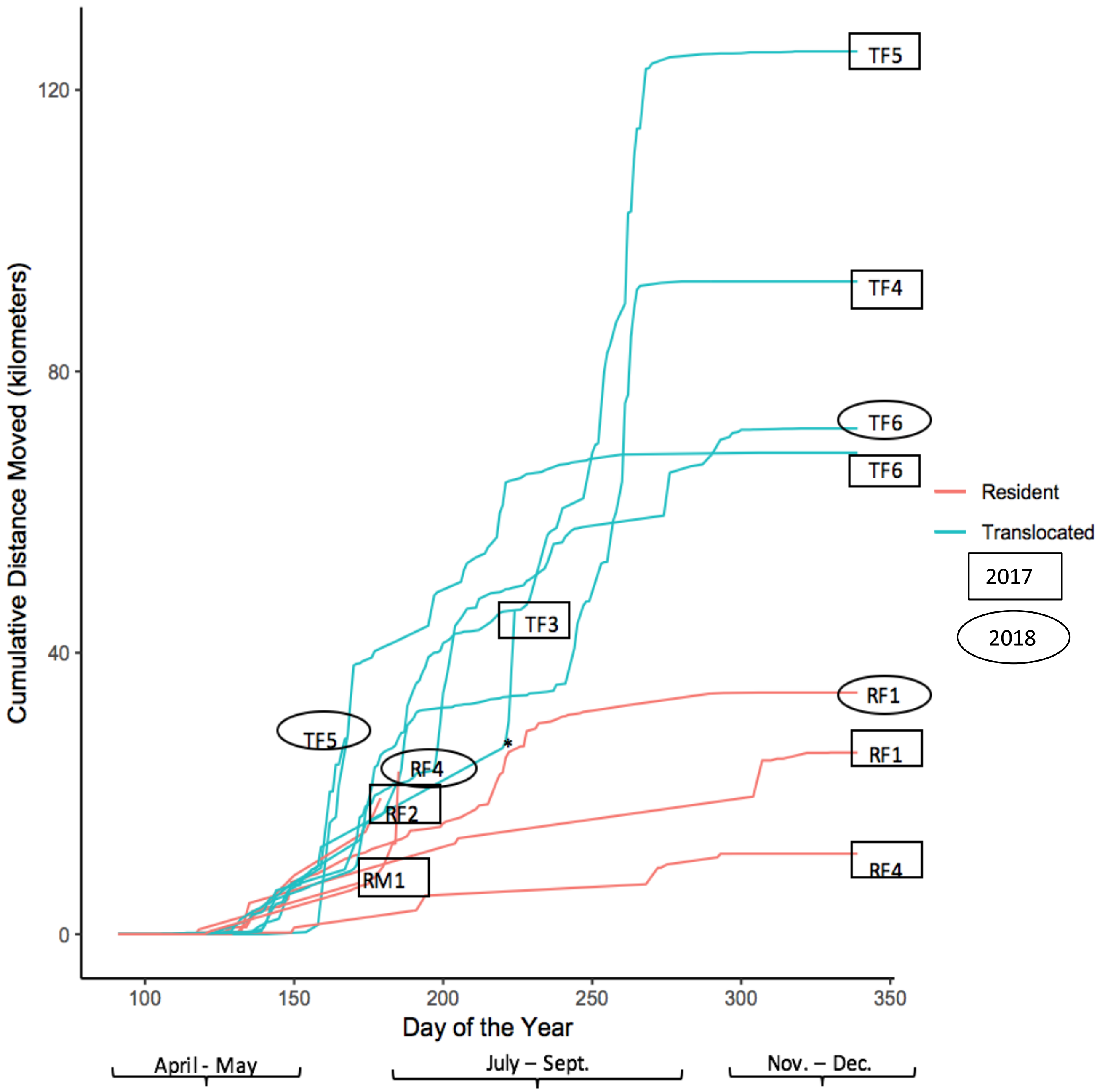

Figure 14. Total distance moved by resident and translocated turtles in 2017 and 2018.

Table 4. Mean daily distances moved by resident and translocated females in the fall, spring, and summer.

	Mean Daily Distance Moved (meters)			
Turtle ID	**Fall 2016**	**Spring 2017**	**Summer 2017**	**Fall 2017**
RF1	102	104	93	173
RF4	34	8	70	164
TF3	105	113	434	NA
TF4	412	100	709	3
TF5	643	123	956	22
TF6	175	117	429	189

3. *Do the translocated and resident turtles have similar home ranges and do they use similar swimming paths when moving in the river?*

I located turtles nearly every day, which allowed me to identify their swimming paths and the characteristics of those paths. Out of 1,309 total observations, resident and translocated turtles were located a mean distance of 36 meters from shore and the farthest distance from shore was 160 meters. The average water current velocity where turtles were located was 0.24 m/s, and the fastest water current speed measured at any recorded turtle location was 0.80 m/s.

In 2017, the home ranges of translocated Northern Map Turtles were larger than resident turtles with some of the lengths nearly quadrupled that of the residents (Table 5). Apart from the newly captured female resident (RF4) who exhibited variability in her home range length, the home range lengths of each resident turtle were nearly the same each year that they were tracked. The home range length of translocated female (TF6) was about 15 kilometers longer in 2018 than in 2017.

Hypothetical least-costly swimming paths were generated using water current data and showed that Strawberry and Motor Islands are crucial stopover points for turtles that are seeking low water current speeds (Fig. 15). The actual paths that resident and translocated Northern Map Turtles used while crossing the river overlaid the hypothetical paths (Fig. 16). There were four occurrences when translocated female turtles crossed the river without using an island as a stopover, however, all such occurrences were downriver movements, and their direct paths were unknown (Fig. 17).

Table 5. Home range length of resident and translocated turtles for each season they were tracked.

			Total Home Range Length (kilometers)			
Turtle ID	**Turtle Origin**	**Sex**	**2016**	**2017**	**2018**	$\bar{x}$
RM1	Resident	M	0.80	0.80	NA	0.80
RF1	Resident	F	6.16	6.19	6.80	6.38
RF2	Resident	F	13.07	11.26	12.77	12.37
RF4	Resident	F	5.83[a]	5.83	14.40	10.12
TF3	Translocated	F	NA	13.93[b]	NA	13.93[b]
TF4	Translocated	F	NA	33.49	NA	33.49
TF5	Translocated	F	NA	48.94	NA	48.94
TF6	Translocated	F	NA	35.79	51.10	43.45

a - Value after anthropogenic displacement was removed

b - Value after movement over Niagara Falls was removed

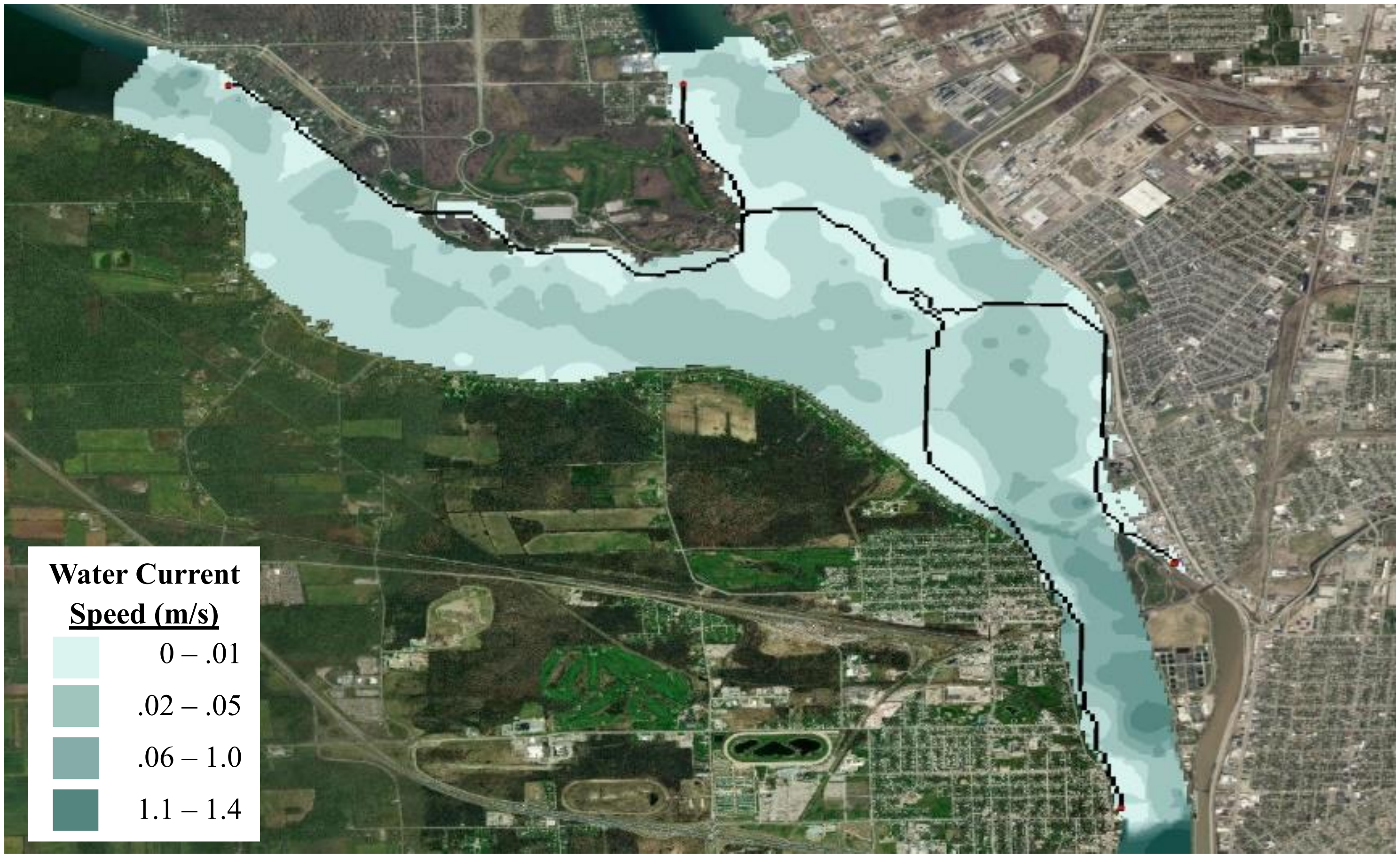

Figure 15. An interpolated surface layer of water current on the upper Niagara River. The black lines are hypothetical least-costly swimming paths.

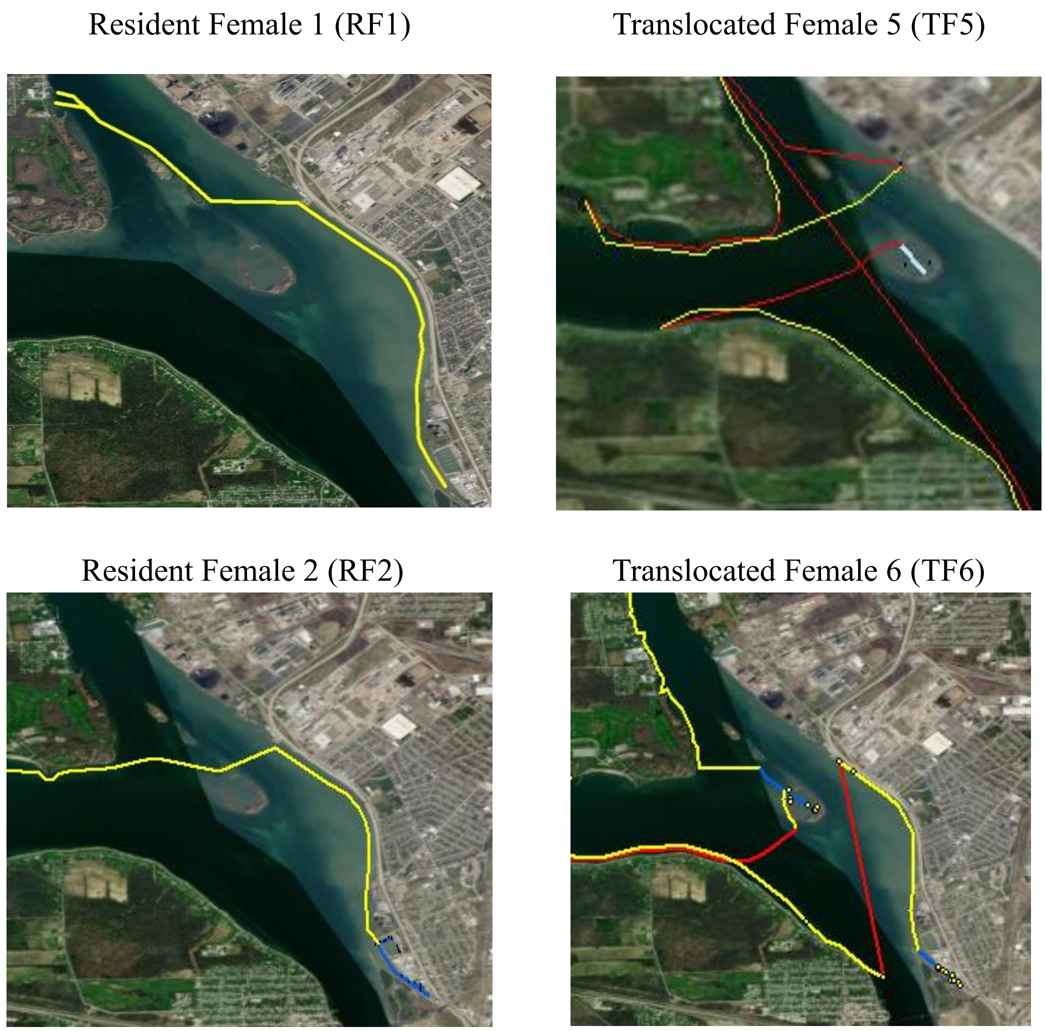

Figure 16. Actual swimming paths of four Northern Map Turtles in the upper Niagara River highlighting the use of Strawberry and Motor Islands as a stopover point when moving upriver.

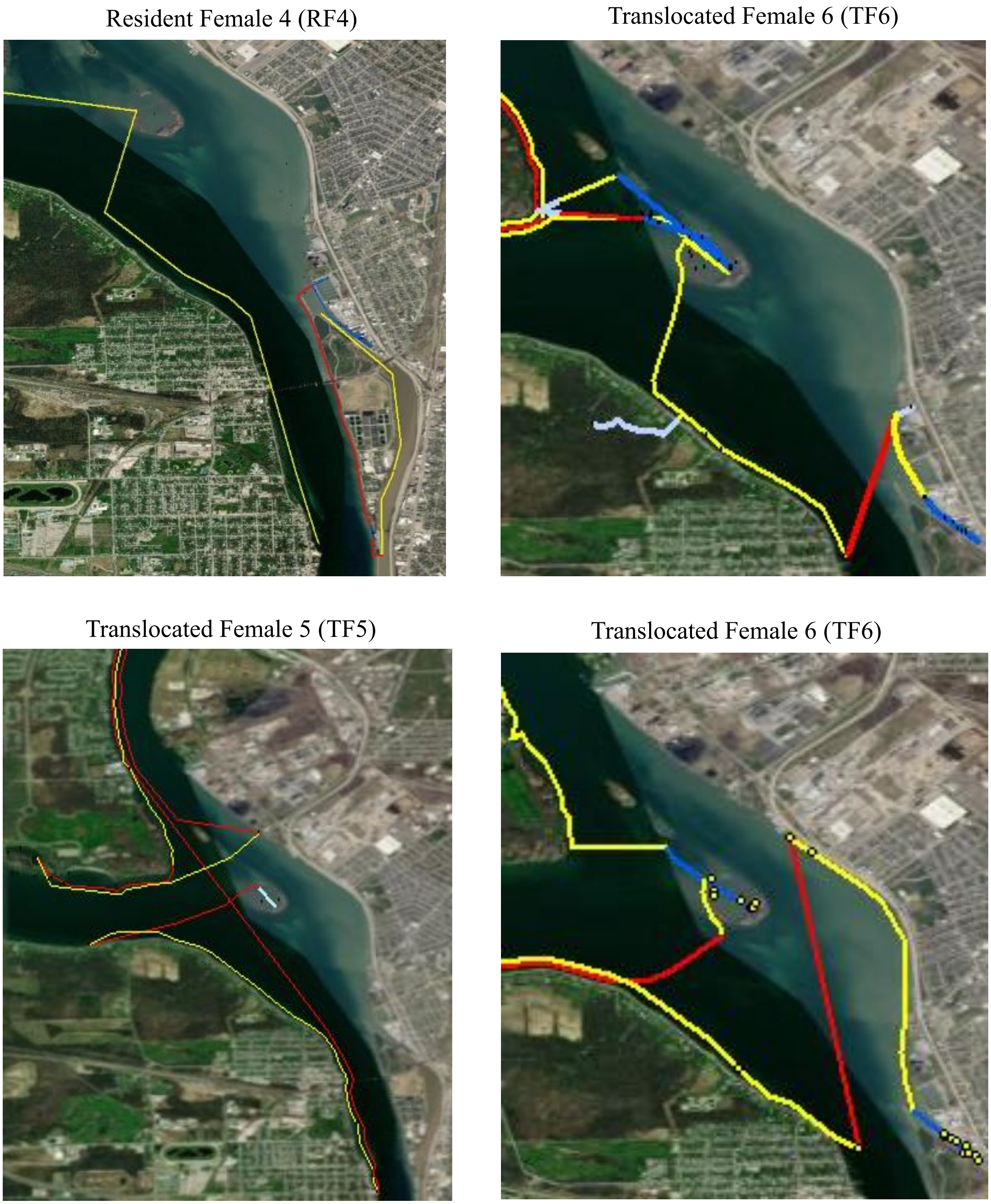

Figure 17. Actual swimming paths of three Northern Map Turtles in the upper Niagara River. The red lines represent downriver movements that bypassed Strawberry and Motor Island.

Further evidence showed that turtles were restricted by water current when the underwater drone was used to video record translocated female (TF5) having difficulty crawling upriver on the substrate (Fig. 18). She was in the flow of the river just offshore from Buckhorn Marsh where the depth was less than 2 meters, and there was a water current speed of 0.60 m/s.

In the following figures the red lines represent downriver swimming paths and yellow lines represent upriver. Locations where a turtle spent longer than five consecutive days were colored with either a light or dark shade of blue, depending on the length of the stay. The light blue lines represent locations where a turtle was present between five and ten days, and dark blue lines represent locations where a turtle was present for longer than ten days.

Figure 18. Translocated female (TF5) crawling against a water current of 0.60 m/s.

4. *Do the translocated turtles initiate brumation at similar times and locations compared to the resident individuals, and do the turtles exhibit hibernaculum site fidelity?*

It was difficult to determine whether water temperature or photoperiod was more influential in the change of activity level for Northern Map Turtles becoming inactive in the fall (Fig. 19) and active in the spring (Fig. 20). Resident turtles became inactive between 17 September and 2 November when water temperatures dropped below 23°C, but some residents continued to move until water temperatures dropped to 12°C. The variability in water temperature when resident turtles became inactive was much greater compared to the temperature range when translocated turtles became inactive. Translocated turtles became inactive between 1 October and 2 November when water temperatures were between 6° and 12°C. They remained active later than some residents, however, the length of their active season was generally not longer than residents' active seasons. Resident turtles became active between 28 April and 23 May when water temperatures were between 7° and 9°C. The variability in water temperature when translocated turtles became active was much greater compared to the temperature range when resident turtles became active. Translocated turtles became active between 4 May and 8 June when water temperature was between 8° and 16°C.

Combining both resident and translocated turtles, the temperature range of initiating brumation was spread over a range of 11^{o}C and a period of 60 days. Awakening from brumation occurred over a similar range of temperatures (10^{o}C) but over a period approximately half as long (33 days). Coming out of brumation is more compressed temporally but remained the same thermally.

Turtle body mass also influenced the length of the turtles' active seasons (Fig. 21). As the body mass of resident turtles increased, they exhibited longer active seasons. The translocated turtles exhibited an inverse effect where the length of their active season decreased as their body mass increased. This was an effect due to origin and body size not sex, as all turtles in the analysis were females.

Throughout the study, seven turtles accounted for 23 hibernacula. Both resident and translocated Northern Map Turtles exhibited hibernaculum site fidelity to individual hibernacula (Fig 22). The minimum distance between a hibernaculum in consecutive years was 5 meters, the maximum distance was 22 kilometers, and the mean distance was 1,054 meters (Table 6). Using the underwater drone, I observed four hibernacula in the spring and fall of 2018 (Fig. 23). Each of the turtles were resting on top of silty substrate, or just partially submerged, which Crocker (2000) similarly observed in Vermont. In the spring of 2018, one female translocated turtle (TF5) was video recorded emerging from her hibernaculum (Fig 24).

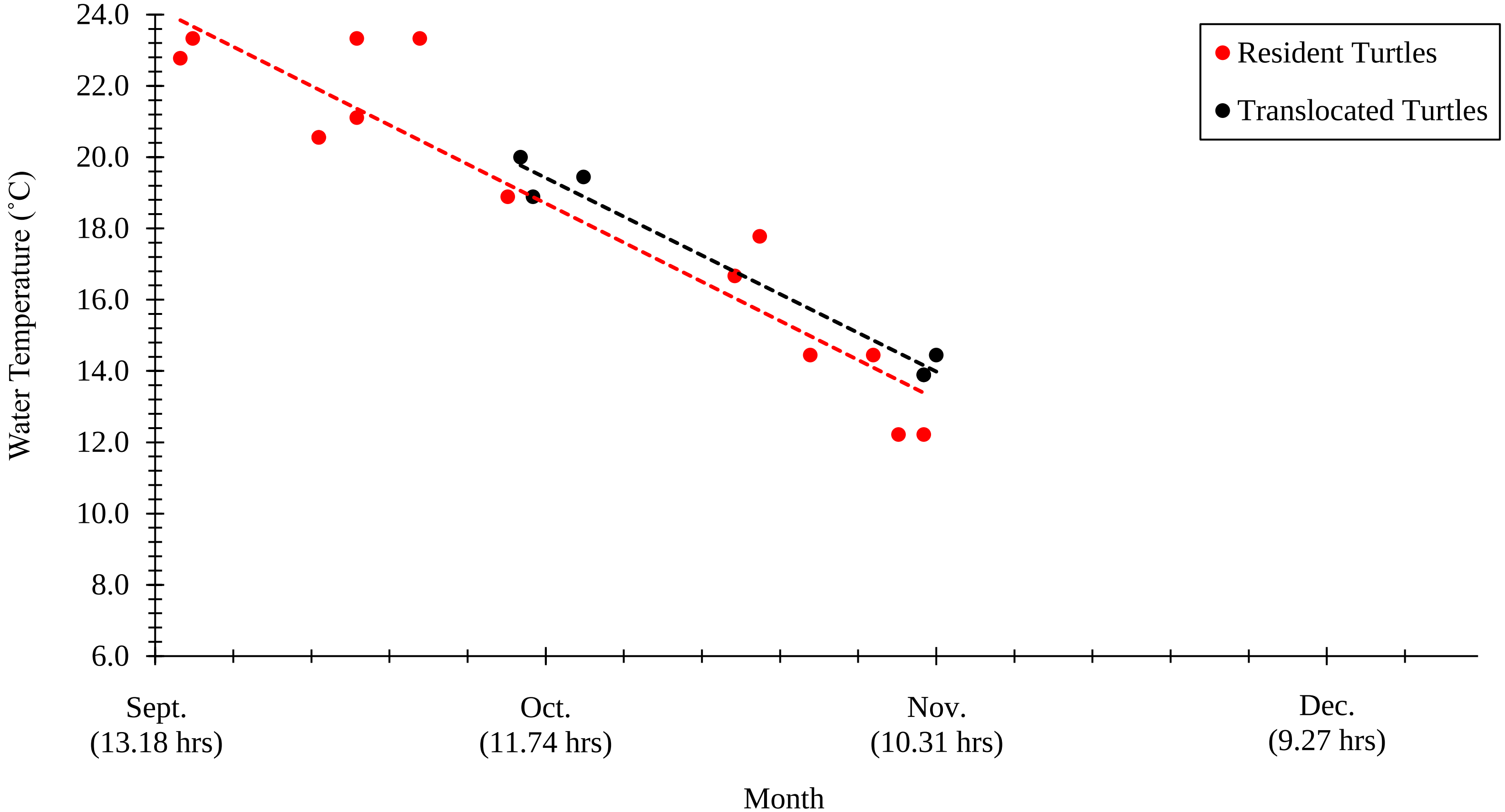

Figure 19. Month and water temperature when four resident and three translocated Northern Map Turtles became inactive. Resident individuals accounted for thirteen data points and translocated accounted for five. The hours in the parentheses under the month indicate the amount of daylight for the first day of that month.

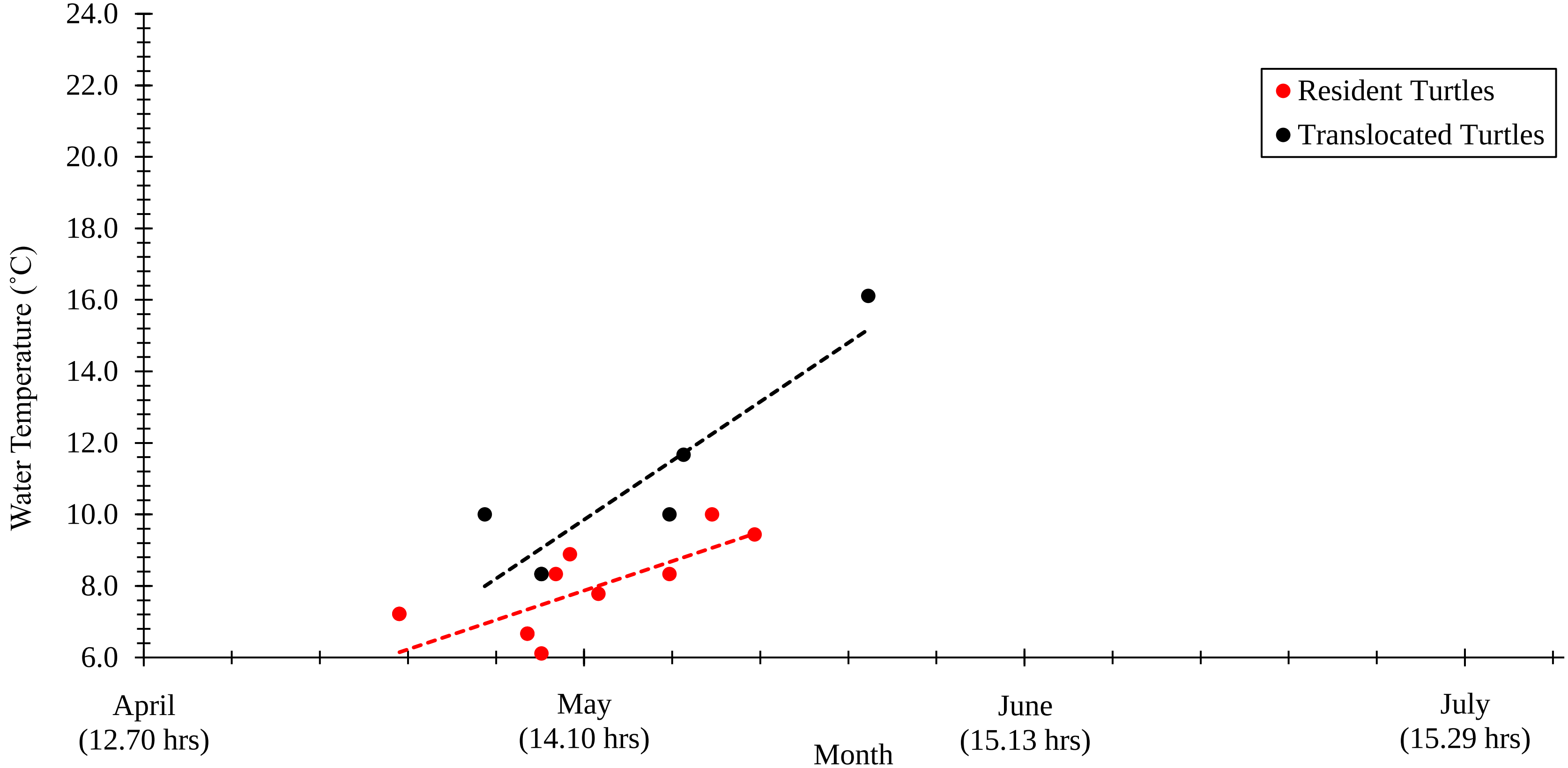

Figure 20. Month and water temperature when four resident and three translocated Northern Map Turtles became active. Resident individuals accounted for eleven data points and translocated accounted for four. The hours in the parentheses under the month indicate the amount of daylight for the first day of that month.

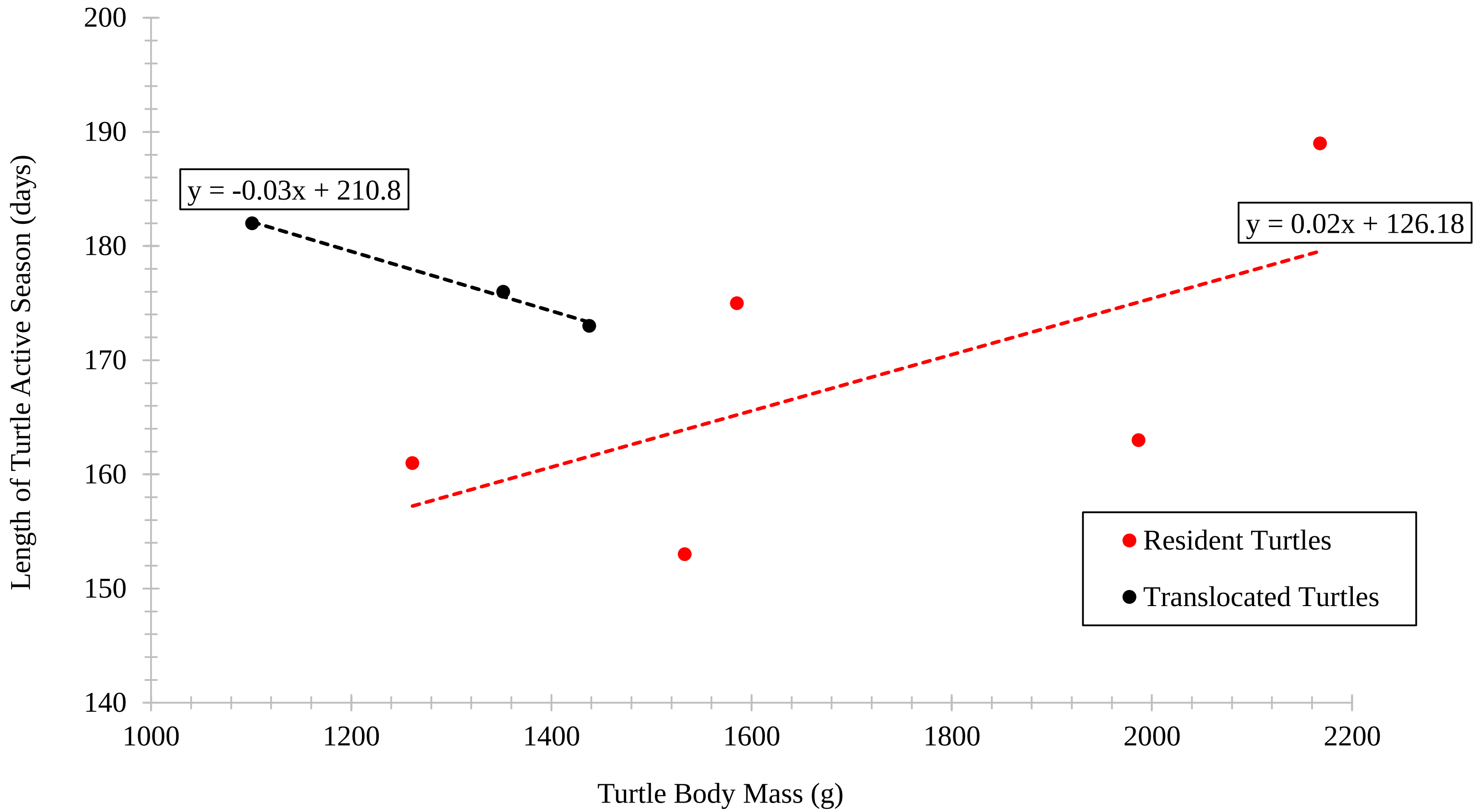

Figure 21. The total length of individual turtle active seasons as a function of their body mass. Data points represent three translocated turtles and three resident turtles. One resident turtle was represented in two separate years.

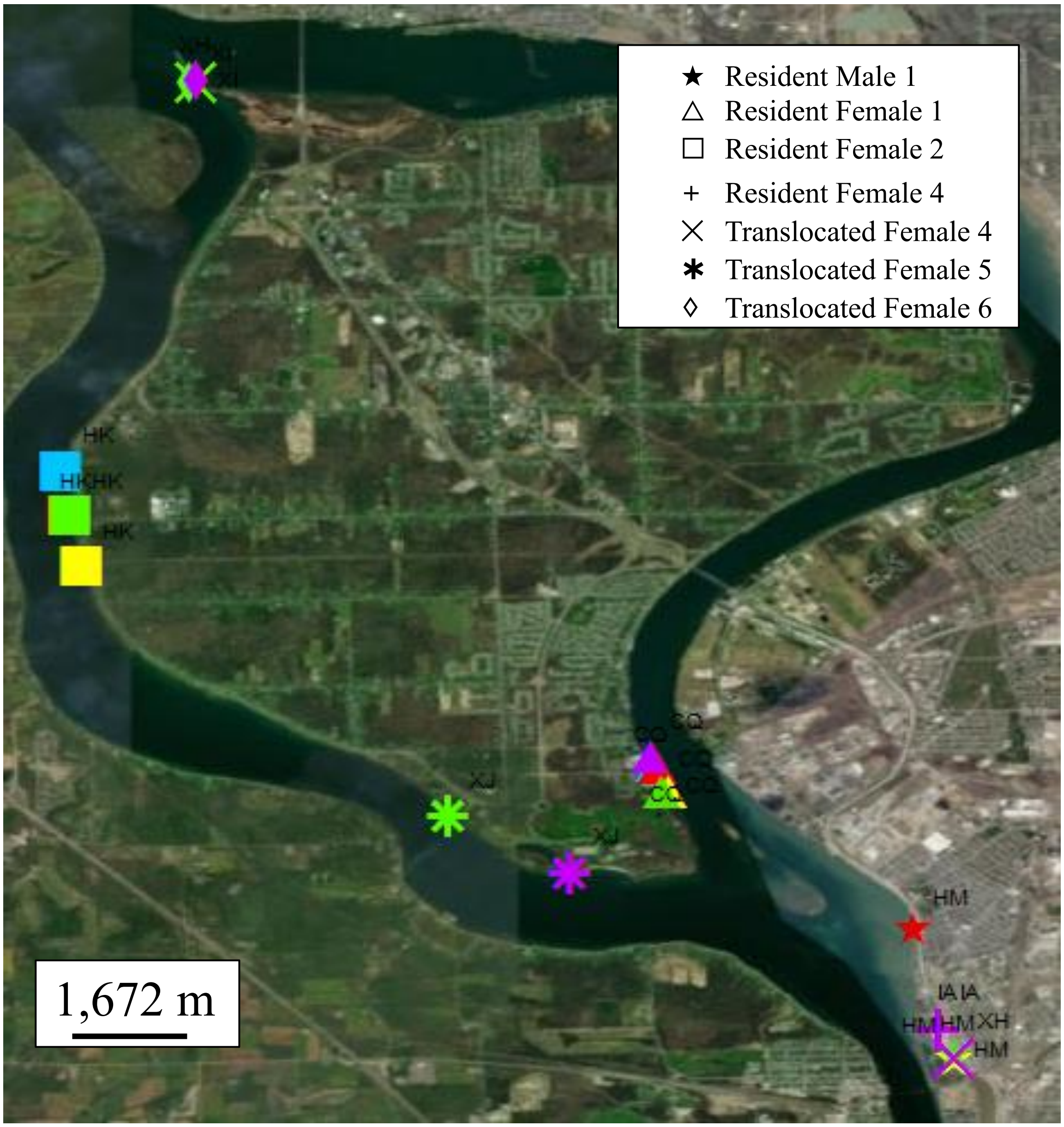

Figure 22. Map of the upper Niagara River showing Northern Map Turtle hibernacula. Seven turtles accounted for 23 sites between 2015 and 2018.

Table 6. The range of distances between individual turtle hibernacula between 2015 and 2018.

Turtle ID	Total Number of Hibernacula	Minimum Distance (meters)	Maximum Distance (meters)	Mean Distance (meters)
RF1	6	38	6021	1758
RF2	4	21	1447	554
RF4*	2	5	5	5
RM1	4	5	53 (2080)	24 (538)
TF4*	2	21563	21563	21563
TF5*	2	71	71	71
TF6	3	1672	6161	3917

* – Turtles that only had two hibernacula identified
( ) – 2014 hibernaculum included in analysis

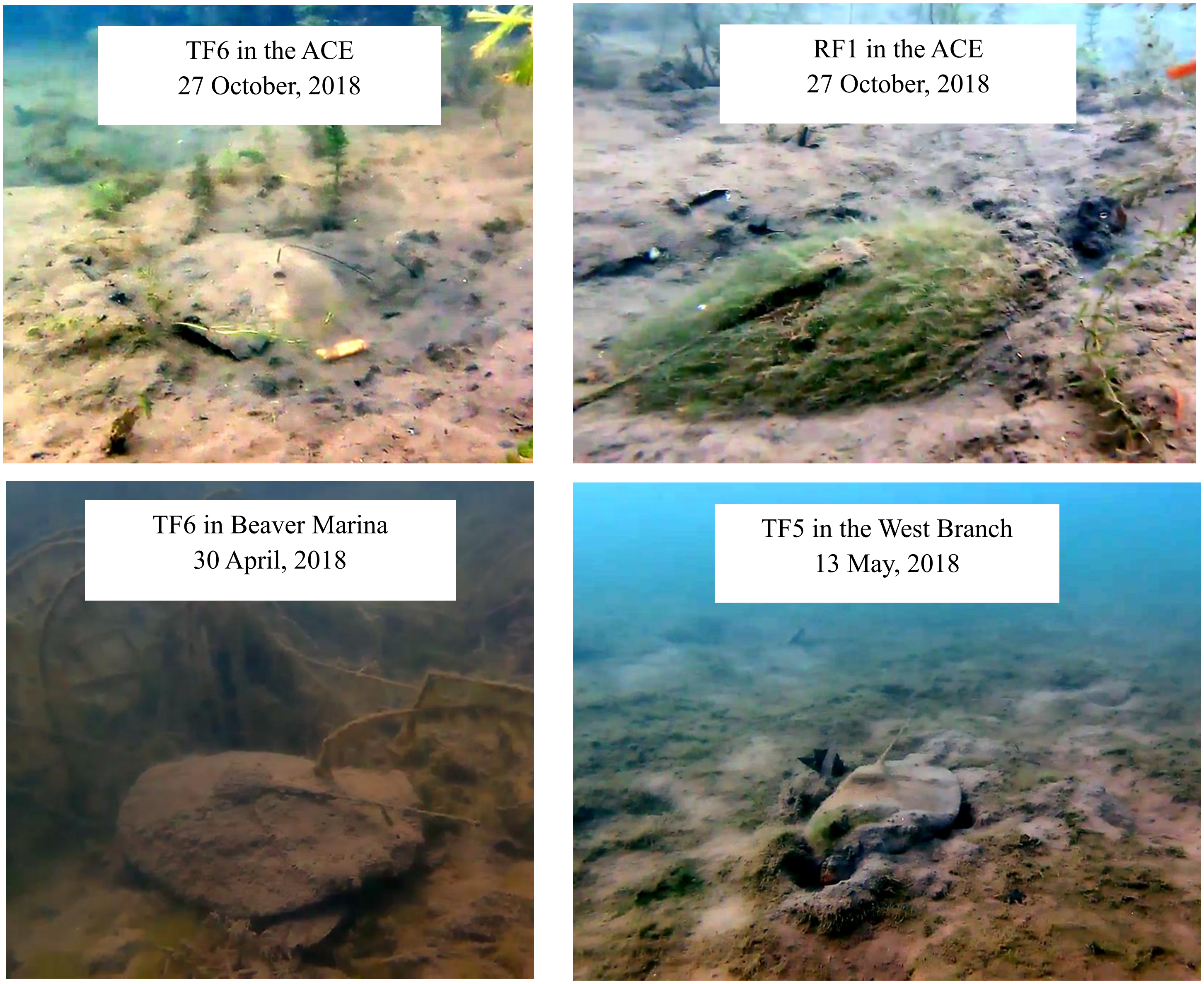

Figure 23. Photographs from the underwater drone showing three Northern Map Turtles in their individual hibernaculum.

Figure 24. Translocated female (TF5) emerging from her hibernaculum in the spring of 2018.

5. Do the resident and translocated turtles use the basking/nesting platforms?

The ACE platform was used extensively for basking, but no nesting occurred. The platforms in BIL were used significantly less, but there were only 69 days when tracked turtles were in BIL compared to 1,053 days in the RMC. Five species of aquatic turtles were observed basking on the platform including the Northern Map Turtle (*Graptemys geographica*), Common Snapping Turtle (*Chelydra serpentina*), Painted Turtle (*Chrysemas picta*), Spiny Softshell Turtle (*Apalone spinifera*), and Red-Eared Slider (*Trachemys scripta elegans*) (Fig. 25).

There were 170 observations of resident and translocated Northern Map Turtles basking throughout the study, excluding the camera trap observations. Both resident and translocated turtles preferred log or deadwood basking substrate to any other material (Fig. 26). The resident Northern Map Turtles used the RMC platform significantly more than translocated turtles but were present in the RMC for greater amounts of time. There was a period of overlap between 29 August and 31 October when resident and translocated turtles were both located in the RMC and during that time period there were only two observations on the platform so no comparison between basking behavior could be made.

Figure 25. Four species of turtles using the ACE platform to bask in the RMC.

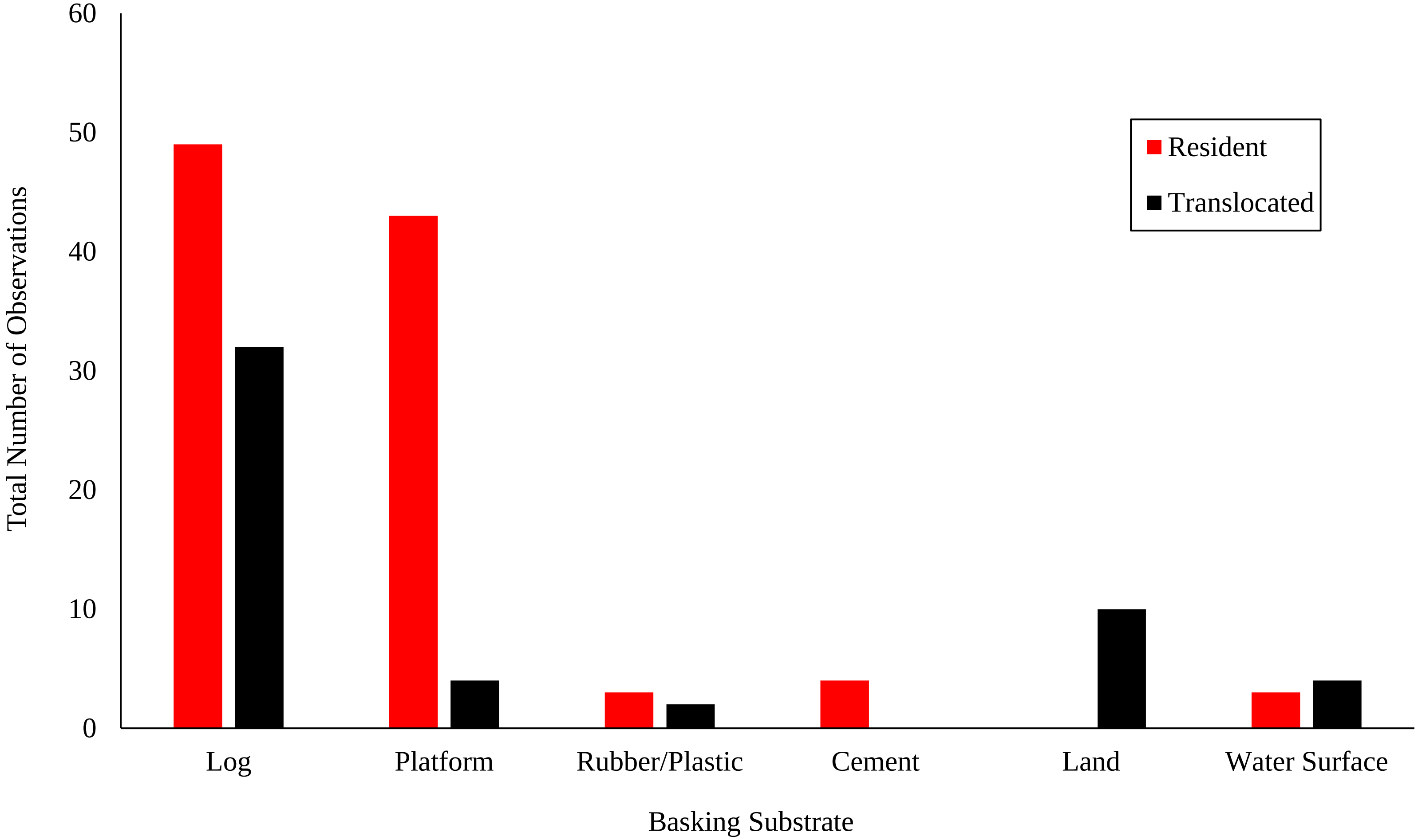

Figure 26. Resident and translocated Northern Map Turtle basking observations and associated basking substrate.

Although no nesting occurred on the platforms, a snapping turtle was observed on top of the sand substrate on the ACE platform in July of 2017. She was seen three separate times between 11:00 PM and 4:00 AM, but no nest was dug. There was also a single egg laid by a painted turtle on the side of the platform. It was analyzed in the lab and found to be unfertilized.

There were two nests found throughout the study. A survey of the Rich Marine boatyard produced evidence of multiple nesting attempts in the area surrounding an excavated nest. This nest was less than 50 meters (Fig. 27) from the nest found in 2014 by Haas (2015). Resident female RF4 was located near the only access point to land on 3 and 4 July 2016 and the other females were not observed moving between ACE and Rich Marina during those days. Because she had only been tracked since spring, this is potential evidence that more than one gravid *G. geographica* used the cement ramp to access the boatyard.

There was another nest located in Beaver Island State Park, less than 50 meters from the lagoon, but it was predated. Every year snapping turtles nest in the lagoon area but their nests are dug up by mink within a week (personal communication with employees at the Beaver Island State Park Nature Center).

Figure 27. The circle represents the cement ramp that turtles used to access the Rich Marine boatyard. The Ns represent two separate nests found within 50 meters of each other in 2014 and 2016.

Discussion

Homing Behavior:

Translocated turtles were released into the upper Niagara River and the surviving individuals remained in the river for most of the study. However, there was evidence of homing behavior when one translocated female (TF4) was located south of the Niagara River in the Buffalo Harbor area, and when two females were in tributaries on the Canadian shoreline (TF5 and TF6).

In late October and early November of 2016 when the translocated Northern Map Turtles were released, they moved downriver the following two weeks. It’s typical for translocated individuals to make extensive movements after a release, yet activity occurring that late in the season is unusual for the species. At the northern parts of *G. geographica*’s range, individuals typically become inactive for the winter season between October and November (Lindeman 2013, Haas 2015). In 2017 the translocated individuals initiated brumation nearly a month earlier than they had the previous year when they were released. Therefore, the initial movements made by translocated turtles after their release were almost entirely toward shore or downriver which was further evidence of the search for hibernaculum rather than dispersal or homing behavior.

Analyzing the direction and distance of movements made by translocated individuals often explains the behavior they are exhibiting. For example, short random movements made by translocated individuals are normally associated with foraging activities, while long directed movements can be associated with homing behavior (Griffith et al. 1989, Burke 1991, Dodd and Seigel 1991, Germano and Bishop 2009). Due to the characteristics of my study site, I was unable to interpret the direction of the translocated turtles' movements as a definitive behavior. The upper Niagara River flows northwest at a heading of 322 degrees and exhibits almost no tortuosity, while the origin of the translocated turtles (Presque Isle State Park in Erie, Pennsylvania) has a heading of 227 degrees from the turtles' release site (Fig. 28). With few exceptions, the direction of flow in the river limited the ability of translocated turtles to move directly toward their origin.

Figure 28. Map showing the orientation of Presque Isle State Park in relation to the flow of the upper Niagara River. The red star represents Presque Isle

Many of the translocated Northern Map Turtles in my study did not survive primarily because of the time of their release. The translocated turtles were in captivity, fed artificial diets, and had limited swimming opportunity for five months. They were then released the last week of October and the first week of November when the species is typically exhibiting brumation.

Homing behavior was difficult to decipher by comparing downriver and upriver movements because the turtles were in an aquatic system that offered only these two directions as options. However, their habitat use and movements compared to resident turtles were most likely associated with homing behavior. During the fall seasons, translocated females exhibited large upriver movements which might have been associated with either homing behavior or the search for hibernacula. In 2018, the two surviving translocated females inhabited the same habitats they had the previous year, which was evidence of not only hibernacula site fidelity, but also familiarity within the river. Although they used the same backwater habitats, they spent less time in each and more time moving in the river.

Two female resident turtles (RF1, RF2) spent nearly their entire 2016 and 2017 summer seasons in the RMC, whereas translocated females (TF4, TF5, and TF6) and a newly captured female (RF4) exhibited the most movement during the summer season, which potentially suggested homing behavior. Two of the translocated females used the entire length of both branches of the river and one made it as far south as Erie Basin Marina. The home ranges of translocated *G. geographica* were quadruple the home range lengths exhibited by conspecifics inhabiting alternative systems, which could also be indicative of homing behavior or the search for alternative habitats.

Evidence showed that two translocated turtles attempted to swim back to Lake Erie. These translocated females *G. geographica* were located on the Canadian shoreline at the most southern location that turtles were ever located within the river. Resident female (RF4) initially captured in 2016, was also located at the most southern location on the opposite shoreline. This turtle was also located in Lake Erie at the end of the 2018 active season. I hypothesized that she was an emigrant from Lake Erie exhibiting homing behavior. One of the translocated females was also located in two creeks on the Canadian shoreline, both of which had an orientation in the direction of Presque Isle State Park.

The clearest evidence of homing behavior was observed when two translocated females were located on the Canadian shoreline and traveled up two separate creeks that allowed them to move in a direction toward Erie, Pennsylvania. The tributaries were shallow, and the turtles traveled less than 2 kilometers before moving back to the river, but the same turtles returned to the creeks the following year showing a clear effort to move toward Lake Erie.

All three translocated females ended up in the RMC at some point in the study. The resident and translocated turtles used similar paths when moving upriver, which often led them to the RMC, where they could not move farther upriver without moving through the Black Rock Lock. There were two turtles that traveled through the lock to the Buffalo Harbor, one translocated female, and one resident female that was newly captured in 2016. Translocated female (TF4) traveled up the Black Rock Lock Canal and was in Erie Basin Marina for almost a week. This individual essentially made it back to Lake Erie but then returned to the RMC, rather than continuing north toward Presque Isle. I hypothesized that the break walls located offshore from the Buffalo Harbor may also prohibit turtles from moving further into the lake by creating an illusion of an impassible cement wall. The water current around the break walls was not measured, but from my observation, the fast current may have also physically restricted movement.

The newly captured resident female (RF4) that also moved through the lock had a home range that was more like the combined home ranges of translocated turtles than resident turtles, which included the Canadian shoreline and areas south of the RMC. I hypothesized that this female was originally from a Lake Erie population and was attempting to move back to Lake Erie, as well. In 2016 she was captured by a fisherman at Broderick Bridge, one of two most southern locations where turtles were found in within the river (Fig. 29). Her path to this location was unknown, but the water current along the American shoreline was thought to be unnavigable due to the fast water current. I hypothesized that RF4 used the Black Rock Lock to move through the canal and was washed out of the culverts into the river (Fig. 30). After she was captured at Broderick, she was moved to Beaver Island Lagoon where she began moving upriver to Strawberry and Motor Islands, across to the Canadian shoreline, and upriver along the shoreline until she reached the other most southern location where turtles were found in the river. The next location where RF4 was found was back at Broderick Park where she remained for the rest of the active season, again her direct path was unknown. I suspected that she could not move upriver past this location. Delevan et al. (2017) found a similar phenomenon where Emerald Shiners were in the same location and unable to swim against the current at the headwaters of the upper Niagara River.

Figure 29. The red lines represent the two southern-most locations where turtles were found in the headwaters of the upper Niagara River. In the orientation of this photograph the river is flowing north.

Figure 30. Culverts that allow flow between the Black Rock Canal and the upper Niagara River.

Distances Moved:

In the summer of 2017, the translocated turtles had mean daily movements that reached up to ten times the mean daily distance moved by residents due to differences in their habitat use. Resident turtles remained in low-current habitats for nearly the entire active season, with most observations occurring in the RMC. Two resident female turtles (RF1 and RF2) spent most of their summer in the RMC making small random movements associated with foraging and were only located in the river when moving to and from their hibernacula, while translocated turtles made long straight movements in the river throughout the entire active season with interspersed periods of time spent in various backwater habitats. The translocated turtles not only moved longer daily distances than resident turtles (Haas 2015) but moved longer mean daily distances than conspecifics in other studies, as well (Flaherty 1982, Richards-Dimitrie and Seigel 2011, Attum et al. 2013).

It was difficult to make comparisons of individuals' movements between years when batteries on some of the transmitters expired, and individuals were often tracked during different times of the year. Resident individuals exhibited similar distances moved every year they were tracked due to their recurring use of the RMC habitat. Translocated female (TF6) moved 5 kilometers more in 2018 than she did in 2017 because her 2018 home range included the entire shoreline of Grand Island (circumnavigated the island). Her movements around Grand Island were direct and there was no time spent in backwater habitats. Again, it was difficult for me to associate these long direct movements with homing behavior because the characteristics of the river facilitated long direct movements. However, it seemed that the turtle was searching for alternative habitat throughout the active season, whether that meant Presque Isle or elsewhere.

Home Ranges:

Resident Northern Map Turtles in the upper Niagara River exhibited similar home range lengths each year they were tracked, apart from the newly captured resident female (RF4). Resident turtles spent most of the active seasons in the RMC and exhibited hibernaculum site fidelity which made their home ranges and daily distances moved consistent. In 2017, the home range lengths of translocated turtles were much longer than residents due to their extensive movements in the river.

In other studies, female *Graptemys geographica* exhibited home range lengths that varied between 1.2 and 8.5 kilometers and males exhibited ranges between 1.7 and 2.1 kilometers in length (Pluto and Bellis 1988, Bennett et al. 2009, Ouellette and Cardille 2011, Richards-Dimitrie and Seigel 2011). In my study, resident female (RF1) exhibited a home range length within the typical range every active season that she was tracked. Resident female (RF2) brumated in the west branch of the upper Niagara River which resulted in long distance movements and home range lengths outside the typical range for female *G. geographica*. Resident female (RF4) exhibited home range lengths within the reported means in 2016 and 2017, but in 2018 her home range length doubled that of her previous year's home range when she moved through the Black Rock Lock Canal to Tifft Nature Preserve on the shoreline of Lake Erie, placing her outside of the reported means, as well.

In the 2016 and 2017 active seasons, the male resident turtle and all the translocated turtles exhibited home range lengths outside of the reported lengths. Male resident (RM1) never left the RMC and had a home range length half that of the shortest reported, while the translocated females moved consistently between backwater habitats throughout the entire active season of 2017.

Swimming Paths:

The similarities between the hypothetical and actual swimming paths of Northern Map Turtles in the upper Niagara River showed that water current strongly influences turtle movements. The underwater drone allowed me to video record translocated female (TF5) struggling to crawl against the flow of the river where the water current was 0.60 m/s. Pluto and Bellis (1986) showed that the swimming ability of Northern Map Turtles increases as a function of carapace length and that the largest individuals were able to swim against velocities of 0.6 m/s. Water current and distance from shore were important habitat predictors of resident and translocated *G. geographica* in the upper Niagara River; turtles stayed within 160 meters of shore in currents slower than 0.60 m/s. Haas (2015) found similar results when he tracked the resident turtles in previous years. Richards-Dimitrie and Seigel (2011) also found that during high flow events in the Susquehanna River, the movements of Northern Map Turtles were restricted and individuals found refuge behind large rocks or logs. In my study, turtles that were traveling upriver from one shoreline to another used Strawberry and Motor Island Complex as a stopover point. The islands create a large area of slow water currents that provide turtles with a refuge from the strong current of the river. Interestingly, the translocated turtles stayed at the stopover location for more consecutive days than resident turtles.

The water current played a role in differentiating male and female Northern Map Turtle habitat use in the upper Niagara River. Resident female turtles were able to navigate the river to find hibernacula and alternative backwater habitats, while male resident (RM1) remained in the RMC throughout my study, and two males that were captured in the RMC during my study remained in the RMC overwinter. When translocated turtles were released in the fall of 2016, two translocated males overwintered in boathouses on the west branch of the river and remained less than 10 meters from shore. They were potentially too small and weak to navigate upriver, which limited their choices for suitable hibernacula.

Brumation:

The timing of fall and spring migrations are extremely crucial to the fitness of an organism. I found that water temperature, photoperiod, and body mass all potentially influence the length of active seasons exhibited by Northern Map Turtles in the upper Niagara River, but water temperature and photoperiod are too closely correlated to determine if one is more influential than the other. In Figures 19 and 20, more vertical trendlines would indicate that photoperiod is more influential than water temperature, while horizontal trendlines would indicate the importance of water temperature. There was a wider range in the date (60 days) when resident and translocated turtles initiated brumation in the fall, than becoming active in the spring (33 days; Fig. 19). Because of the thermal inertia of water, hours of daylight in the spring and fall change more rapidly than changes in water temperature. The difference in these rates may be important when studying the length of turtles' active seasons.

Excluding the movements of translocated turtles in the fall of 2016, all resident and translocated turtles throughout the study initiated brumation between 17 September and 2 November when water temperature dropped to 23°C. This is a typical behavior of *G. geographica*, who begin their search for hibernacula in late September and October (Lindeman 2013). Haas (2015) found that in the fall, once the water temperature reached 22℃, resident turtles left their summer refuges to find hibernacula. The turtles that I monitored behaved similarly and initiated brumation between 13°C and 24°C. The coldest temperature in which turtles remained active in the fall and became active in the spring was 13°C and 6°C, respectively.

In the upper Niagara River, there was a positive correlation between body mass and the length of the active season for resident turtles. The largest individual tracked throughout the study was resident female (RF1) with a mass of 2,168 grams. The next largest individual was resident female (RF4) with a mass of 1,586 grams. The largest resident female turtle stayed active later in the season which caused her to have a longer active season overall (Fig. 21). This made sense since the thermal inertia of an ectotherm increases as a function of body mass. Bulté and Blouin-Demers (2010) showed that as the body mass of Northern Map Turtles increased, the daily range of body temperatures decreased. This may allow larger animals to wait longer into the season to migrate to their hibernacula. Larger body size may also promote the storage of energy for the long northern winters (Lindeman 2013). However, the translocated turtles exhibited an inverse effect, showing a decrease in active season length as their body mass increased. I hypothesized that unfamiliarity with the river had more of an effect on the active season length than their body mass. Translocated turtles being less familiar with the river may have migrated earlier to ensure finding a suitable site.

Male *G. geographica* are known to be more active than female conspecifics after finding a hibernaculum, which may cause higher rates of displacement and a higher probability of being transported by water currents. Their small mass most likely restricted their movements within the river and influenced their movements into the RMC, as well. All unmarked map turtles that were captured in the RMC were captured in early May and late October when *G. geographica* typically display their largest home ranges due to movements associated with finding hibernacula. Two unmarked male Northern Map Turtles were captured in the fall of 2016 and died over winter in the RMC. They were last located in the channel that connects the ACE to Rich Marina and their signals remained there until the transmitter batteries expired in June, but their carcasses were never recovered. Both turtles had a body mass under 500 grams which potentially provided the turtles with insufficient energy reserves to survive the winter.

The largest resident female (RF1) exhibited hibernaculum site fidelity every year, except in 2018 when she stayed in the RMC. Interestingly, the hibernaculum in the RMC was located within 2 meters of a translocated female (TF6). This was the only evidence of a "communal hibernaculum" seen in my study, however other populations of *G. geographica* typically exhibit this behavior (Vogt 1980, Pluto and Bellis 1988, Ultsch et al. 2000, Carrière et al. 2009, Richards-Dimitrie and Seigel 2011). Smaller *G. geographica* individuals overwintered in the RMC in previous years and resident female (RF1) still left, but the presence of a female closer to her size may have enticed her to stay in the RMC.

Three translocated females initiated brumation in late September 2017, one month earlier than in 2016 when they were searching for hibernacula in mid-November. After we captured the translocation prospects from Presque Isle State Park, the New York State Department of Conservation Albany, NY office mandated a quarantine of the translocated turtles until the last week in October 2016. The turtles were held in captivity for five months with limited swimming opportunities and fed an artificial diet. The turtles stopped feeding and became lethargic approximately three weeks prior to their release in 2016. This combined with the release of the turtles too late in the season most likely led to a poor survival rate the first winter.

Studies have shown that waking an organism up during brumation causes shock and can be fatal (Crocker et al. 2000), which would explain the four mortalities in the winter of 2016. The late release of the translocated turtles may have prohibited them from finding hibernacula with the proper flow and oxygen regime. Northern Map Turtles require well-oxygenated water to survive overwinter (Crocker et al. 2000, Reese et al. 2001). Each year that the resident turtles were tracked, they began their fall migration at least a month before they became inactive, providing enough time to find an appropriate hibernaculum.

Translocated male (TM3) moved downriver an average of 1.95 km per day for the first four days after his release. The mean daily distance moved by TM3 was extensive compared to the typical daily movements made by male *G. geographica* in other studies, especially in November when turtles have begun brumation (Lindeman 2013, Haas 2015). On 1 November 2016 translocated male (TM3) was observed in the river on top of a large rock that was located less than 5 meters from shore. I suspected that he was avoiding the current rather than basking to fulfill a physiological requirement.

Northern Map Turtles are known to exhibit hibernaculum site fidelity (Graham et al. 2000) and four out of four residents and two out of three translocated turtles in my study exhibited extreme site fidelity. Translocated turtles in my study were released in 2016 and in the fall of 2017, two out of three turtles were familiar enough with the river to be found within 2 kilometers from their hibernacula the previous year. One female resident turtle (RF1) had a total of six hibernacula recorded. Resident female (RF1) was in the east branch of the river every year, aside from 2018, when she brumated in the RMC. Excluding the hibernaculum in the RMC, the maximum distance among her hibernacula was 580 meters.

Resident female (RF4) was captured in the spring of 2016 and returned to the RMC in the fall to brumate. She brumated in Rich Marina, less than 1 meter from shore, in an area with no water current (0.0 m/s). *G. geographica* require well-oxygenated water to survive overwinter (Crocker et al. 2000, Reese et al. 2001) and although dissolved oxygen concentration was not sampled in this location, I predicted there would not be enough. However, RF4 was located directly next to an aerator, which evidently supplied enough dissolved oxygen in the surrounding water for her to survive overwinter. The following winter she exhibited hibernaculum fidelity and brumated less than 5 meters from her 2016 hibernaculum.

All Northern Map Turtles that were observed in their hibernaculum were resting on top of or partially submerged in silty substrate. Other studies also observed individuals lying motionless on the substrate (Richards-Dimitrie and Seigel 2011). Photos and videos taken with the underwater drone showed multiple depression marks in the substrate surrounding an overwintering site. Using telemetry alone would not have detected movements of less than 5 meters.

Future research on active season length of Northern Map Turtles may focus on the cue hierarchy that influences changes in activity level, and the environmental factors that cause the expression of the “Clock” gene. Saino et al. (2017) showed that phenological variation in Barn Swallows can be altered by manipulating the “Clock” gene. The expression of the gene caused the birds to leave their overwintering sites early, and ultimately increased their breeding success.

Conclusions

The translocation portion of the project was not executed as proposed, and the release of the translocated turtles was unnecessarily delayed by four months which caused several issues. The translocated turtles were released late in the active season after being fed an artificial diet for five months with limited possibility for movement because of their confinement. After the first winter in the river there were four surviving females of the ten turtles that were released. The translocated Northern Map Turtles that survived through 2018 remained in the upper Niagara River for most of the study but exhibited signs of homing behavior. One female turtle was located south of the Black Rock Lock in the Erie Basin Marina for one week, and then moved back into the river. Her and another translocated female utilized the Canadian shoreline including two tributaries that enabled them to move in a direction towards Presque Isle State Park. This was the most substantial evidence for homing behavior, especially since residents had not been found on the Canadian shoreline during my study.

Resident turtles spent nearly their entire active seasons in the RMC which was a much longer time than translocated turtles. This resulted in more basking events on the ACE platform by resident turtles. Cameras from each platform showed that the total time tagged turtles spent basking on the platforms ranged from almost no basking on BIL platforms to extensive basking on the ACE platform. No nests were found on the platforms, but there were two events when snapping turtles exhibited nesting behavior on the nesting substrate. There was another Northern Map Turtle nest found in Rich Marine boatyard and although the eggs were predated, this again suggested that the accessibility to terrestrial nesting substrate was not the issue in this location, but rather the quality of habitat.

Restored habitats in the upper Niagara River were used extensively by both resident and translocated turtles. The translocated females spent long periods of time in restored habitats on the upper Niagara River, were observed basking, and gained body mass throughout the active season. I wanted to analyze the mass gained in specific habitats, but Northern Map Turtles were not captured immediately before and after spending time in a backwater habitat. A second portion of the study compared the mass of the translocated turtles to the mass of the turtles that inhabit Presque Isle State Park (Karcher 2019).

Northern Map Turtles typically exhibit the highest growth rates at the beginning of the active season (Lindeman 2013, Vogt et al. 2018), which may explain why tagged turtles remained in habitats for extended periods of time at the beginning of the season, before making larger upriver movements. When resident and translocated turtles became active in the spring, they moved upriver and stopped in the backwater habitat nearest their hibernacula. Resident female (RF2) remained in BIL for two weeks after becoming active, and then made large upriver movements to the RMC. Resident female (RF1) also exhibited this behavior and stopped in Strawberry Island Lagoon for a few days before continuing her movements upriver to the RMC. Translocated turtles that brumated at the northern end of Grand Island spent time in Buckhorn Marsh and Big Six Mile Creek after becoming active in the spring. I suspect that translocated turtles spent time in these areas more out of convenience than preference.

Almost all backwater habitats on Grand Island were used by resident and translocated turtles (Beaver Island Lagoon, East River Marsh, Big Six Mile Creek, Buckhorn Marsh, etc.), but the presence of turtles alone was not adequate evidence of suitable habitat. Quantitative habitat surveys were not conducted to evaluate physical characteristics, food abundance, or basking structure availability in restored habitats of the upper Niagara River. However, Strawberry and Motor Islands, and the RMC were inhabited by Northern Map Turtles. The island complex created an area of refuge from the flow of the river, like an island complex in the Susquehanna River that provides the same relief (Richards-Dimitrie and Seigel 2011). The RMC was a summer refuge used by almost all tagged turtles.

The hydrology of the upper Niagara River is another potential threat to aquatic organisms. The eastern end of Lake Erie funnels into the Niagara River causing extremely fast water velocities at the headwaters and most likely facilitates the movement of aquatic organisms. When turtles move into the river from the lake, the strong water current at the headwaters of the river, along with the Black Rock Lock system, may prohibit turtles from moving back upriver to Lake Erie. The RMC is located directly north of the lock system and is the first backwater habitat that organisms encounter when moving into the river. The RMC has less than 1.0% unobstructed shoreline, has areas of heavy boat traffic, and is adjacent to a boatyard where the substrate is potentially unsuitable for turtle nesting. In addition to being a physical trap, this area may also be an ecological trap habitat that decreases the fitness of turtles, but is still preferred despite the availability of more-suitable habitats elsewhere (Boal 1997, Donovan and Thompson 2001, Battin 2004, Mannan et al. 2008). It provides turtles with an abundance of food and basking opportunities but increases their risk of boat mortality, has limited suitable nesting substrate, and shows evidence of pollution (Johnson 2017).

The RMC is also characteristic of a sink habitat exhibiting a greater rate of mortality than recruitment, with no sign of local reproduction (Kreuzer and Huntly 2003). All unmarked turtles that were captured in the RMC were captured before June and after October when *G. geographica* exhibit longer daily movements associated with migration from and to hibernacula, respectively (Richards-Dimitrie 2011, Haas 2015). Individuals from other populations may encounter the RMC during these migrations. Without genetic testing I was unable to determine from where the unmarked Northern Map Turtles were emigrating.

There are several possible Northern Map Turtle source populations located along the northern and southern shorelines of Lake Erie (Ernst et al. 1994, Lindeman 2013). There were multiple sightings in the Buffalo River (personal communication with the general public, employees at Buffalo Niagara Waterkeeper, and NYSDEC biologists), which could suggest the Buffalo River is a source population. However, tributaries in Western New York have not been surveyed and therefore the possible source populations are unknown.

Evidence from my study showed that fast currents at the headwaters of the upper Niagara River create a hydrodynamic barrier for aquatic turtles that are swimming upriver, unless turtles opportunistically utilize the lock system. Very little research has been done to study the occurrence or the ability of aquatic organisms to move in and out of the river. However, Delevan et al. (2017) and Allen et al. (2017) created a hydrodynamic model and collected data in the field showing that Emerald shiners (*Notropis atherinoides)* are unable to swim from the river to Lake Erie due to the sustained high current velocity at the headwaters. I hypothesize that the water current at the headwaters limits upriver movement and causes aquatic turtles to inhabit the RMC habitat. The presence of translocated turtles in the RMC, along with the least-costly swimming paths, suggested that when turtles are swimming upriver, they are funneled onto the Tonawanda shoreline and then into the RMC habitat. Bennett et al. (2009) showed that habitat fragmentation influenced the sex ratios of Northern Map Turtles in Ontario and that the sex ratio favored females in fragmented sites compared to control sites. Similarly, the Northern Map Turtle sex ratio in the upper Niagara River was skewed to favor females throughout the study and became more disproportionate by the end of the study. Alternatively, studies have shown that sex ratios in freshwater turtle populations favor males due to road mortality of gravid females that make large overland movements to nest (Baldwin et al. 2004, Aresco 2005, Steen et al. 2006, Wnek et al. 2013). The number of *G. geographica* in the Niagara River varied throughout the entire monitoring period, but the number of females was consistently higher than the number of males. The population in the upper Niagara River may be skewed due to the strong water current in the river and the inability of males to leave backwater habitats to find suitable hibernacula. Even female map turtles which are much larger than males have trouble moving in some areas of the river.

Conservation Management and Future Implications

Habitat Fragmentation:

The RMC habitat is characteristic of an ecological trap where turtles find foraging and basking opportunities, but are threatened by pollution, poor nesting substrate, and motorized boats. Future large-scale habitat surveys conducted on the Niagara River could quantitatively identify the trap habitats (Boal 1997, Donovan and Thompson 2001, Battin 2004, Mannan et al. 2008). The most unique characteristic of the RMC habitat is its location in the river. Not only is the RMC a potential ecological trap, it's physically isolated from Lake Erie by the strong water current at the headwaters of the river and the Black Rock Lock. The RMC is the first backwater habitat encountered when an organism moves from Lake Erie directly into the upper Niagara River, and the last habitat encountered when moving from the river to Lake Erie, by way of the river. Scajaquada Creek and the Buffalo River are both backwater habitats located between the river and the lake. However, they are only accessible through the Black Rock Canal. Freshwater turtles that opportunistically use the Black Rock Lock can reach these habitats, and during my study this occurred twice. Little research has been conducted to study the impact of lock systems on the movement of aquatic turtles, but locks share similar characteristics with dams and weirs that cause habitat fragmentation and declines in freshwater turtle populations (Bodie 2001, Bennett et al. 2009). Future research in the Black Rock District of Buffalo, NY could further investigate the effects of the lock system on the movement of aquatic organisms between Lake Erie and the Niagara River. Although the upper Niagara River habitats seem to be disconnected from Lake Erie habitats, there are several management techniques that could increase connectivity between habitats, or benefit aquatic organisms in other ways.

Aquatic organisms that attempt to move between Lake Erie and the Niagara River may benefit from a revised management plan for the Black Rock Lock system. Currently, when there are no vessels moving through the canal, the lock doors remain closed at both ends. Leaving one end of the lock open when it is not in use may allow aquatic organisms to move more freely through the lock. However, the movement of aquatic invasive species should also be considered.

The development of a fish passage is another conservation effort that has reduced the impact of dams on fish populations. Fish passages are used to increase habitat connectivity and ultimately, the flow of genes between populations (Wofford et al. 2005). In 2018 the Army Corps of Engineers restored an interior pond on Unity Island, adjacent to the Black Rock Lock and the RMC (Unity Island Aquatic Plant Control www.lrb.usace.army.mil). The Unity Island pond could potentially serve as an alternative summer refuge for aquatic turtles or nursery habitat for juvenile turtles that are hatched out in the RMC habitat. However, the pond is also in a suitable location for the development of a fish passage to connect the river and lake habitats by providing aquatic organisms an opportunity to bypass the Black Rock Lock and avoid the headwaters of the Niagara River. Continued monitoring of turtles in the river would be required to determine if the Unity Island habitat is used, and if turtles use the passage to move through the Black Rock Canal.

The lack of recruitment exhibited by Northern Map Turtles in the upper Niagara River could be addressed by developing nesting habitat along shorelines. After my study, shoreline restoration projects being conducted on Little Beaver Island and Buckhorn Marsh/Sandy Beach on Grand Island, New York incorporated turtle nesting habitat into the designs. Collaboration with Dr. David Speiring with the New York State Parks and Recreation resulted in the deposition of sandy substrates on the shorelines, and the creation of access ramps to facilitate movement between the aquatic and terrestrial environment (Fig. 31). Another potential nesting site worth investigating is located between the Army Corps of Engineers and Rich Marina property. The site is a narrow strip of land that turtles could access from the ACE, and could remain in proximity to abundant food sources, basking opportunities, and refuge from human disturbance.

In conjunction with the creation of artificial nesting sites, fencing and monitoring would increase the chances of reproductive success by reducing the threat of predators and other disturbances.

Public Engagement and Social Media:

With any ecological field study, the cooperation of the public is greatly appreciated, and often necessary. In my study, the public was also a source of information. There were several times that tagged Northern Map Turtles were located by the public. I wrote Facebook posts on wildlife photography pages to see if and where Northern Map Turtles had been sighted in the area. Two pictures were posted on Facebook by a wildlife photography group that had seen basking Northern Map Turtles with transmitters attached their carapaces and I was able to confirm the location of the turtles. I also provided a phone number on the radio transmitter of all turtles to allow anglers to contact us if the turtles were ever captured.

Citizen scientists have reported sightings for fishes (MyFishCount), birds (Cornell Lab of Ornithology's eBird), reptiles and amphibians, and even roadkills on several applications. This method of surveying could be used for freshwater turtles, as well. However, in order to produce reliable data, photographs would need to be uploaded as supporting evidence for the correct identification of the organism. Currently, the general public can post pictures of any organism on the iNaturalist application, and before the sighting becomes “research grade,” the identification needs to be verified by two other members of the public.

Figure 31. Riparian restoration on Little Beaver Island that incorporated characteristics of turtle nesting habitat.

Translocation:

During translocation projects, the suitability of the release site is extremely important to the survival of the translocated individuals. The capture and release of animals should also be conducted at biologically-suitable times during the season. As learned in my study, future translocation projects may benefit from capturing organisms before extended periods of inactivity, but with enough time to find suitable brumation sites. At northern latitudes where turtles initiate brumation between the end of September and beginning of November, it may be beneficial to release translocated turtles into their new habitat in September, which may encourage them to immediately find a hibernaculum and exhibit site fidelity in the spring when they become active.

Basking/Nesting Platforms:

There was no nesting activity observed on the platforms in my study. I hypothesize that the size of the platform and the proximity to the water may have discouraged nesting. Future restoration projects that incorporate turtle nesting habitat into the shoreline design should consider the composition and quality of the nesting substrate, the distance of the site from the water, the height of the mound, and the accessibility for turtles to reach land. In Ontario, Northern Map Turtles were observed laying eggs in large sandy areas at a mean distance of 37.5 meters from the water (Steen et al. 2012), and 2 meters above water level in order to protect their nests from drowning (Lindeman 2013).

Turtle species that are known to bask allow for the unique opportunity to conduct visual surveys, and *G. geographica* bask for an average of five to seven hours a day between late May and early July (Lindeman 2013). In my study, the cameras mounted to the basking/nesting platforms allowed me to determine the diversity of freshwater turtle species located in the ACE and BIL. In future studies, cameras could be mounted on a tree or a post to survey turtle populations in areas where aggregated basking occurs. Man-made rafts and time-lapse cameras were effective in showing the presence or absence of species in Illinois (Bluett and Cosentino 2013; Fig. 32).

Figure 32. *Chrysemys picta* basking on a man-made raft and photographed with a time-lapse camera in Lee County, Illinois, USA, 2011 (Bluett and Cosentino 2013).

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Appendix

The following appendix consists of Figures 33 through 66 which illustrate the swimming paths of four resident and eight translocated Northern Map Turtles. Swimming paths were generated with over 1,300 observations obtained using telemetry. The maps are color coded to represent direction of movement within the river. The red lines represent downriver swimming paths and yellow lines represent upriver movements. Locations where a turtle spent longer than five consecutive days were colored with either a light or dark shade of blue, depending on the length of the stay. The light blue lines represent locations where a turtle was present between five and ten days, and dark blue lines represent locations where a turtle was present for longer than ten days. Dates followed by an asterisk indication the location of a hibernaculum.

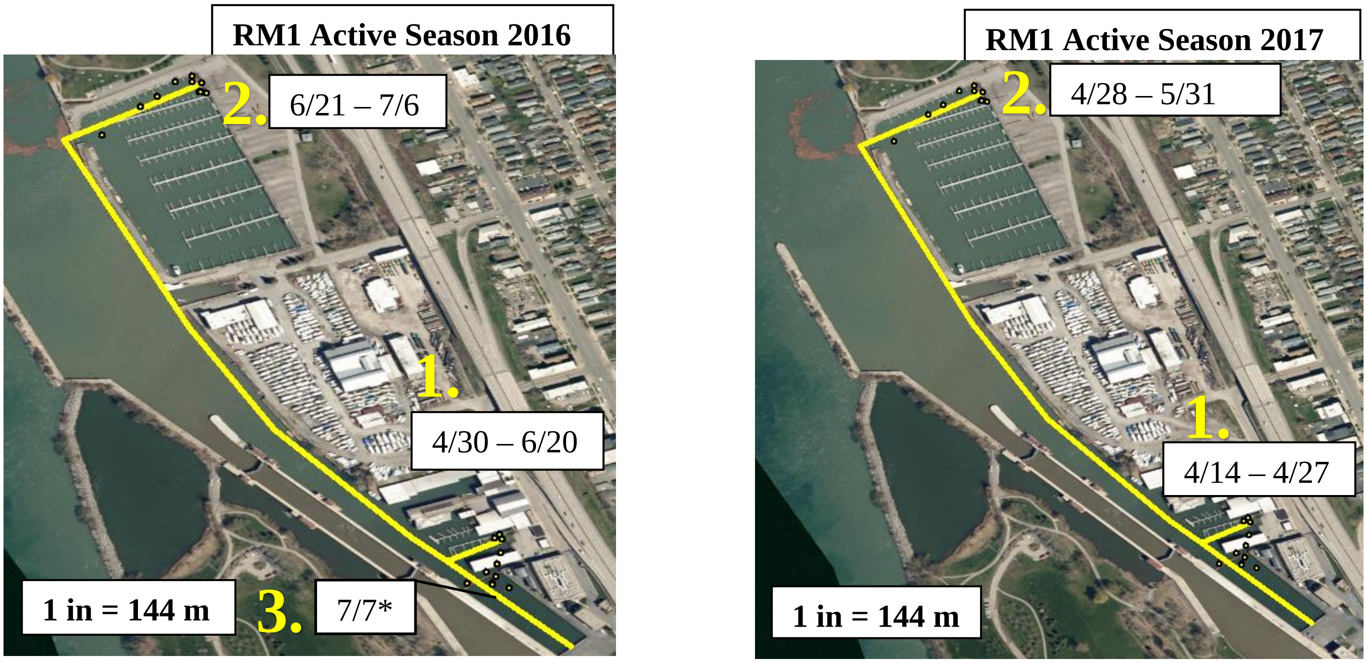

Figure 33. Home range of resident male *G. geographica* (RM1) in the active season of 2016 and 2017.

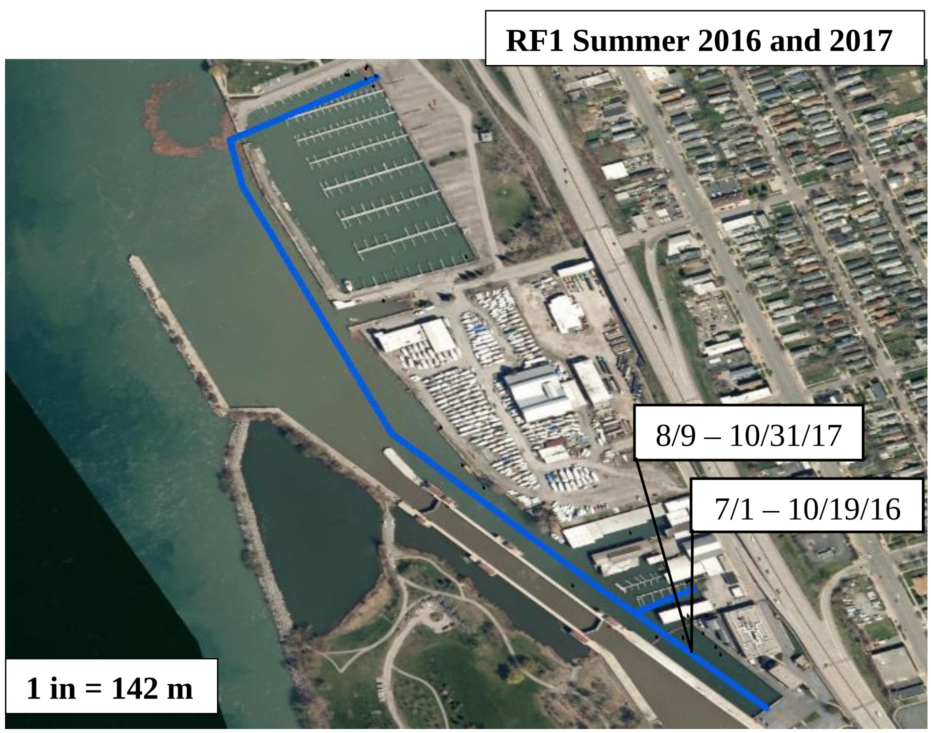

Figure 34. Home range of resident female *G. geographica* (RF1) in the summer of 2016 and 2017.

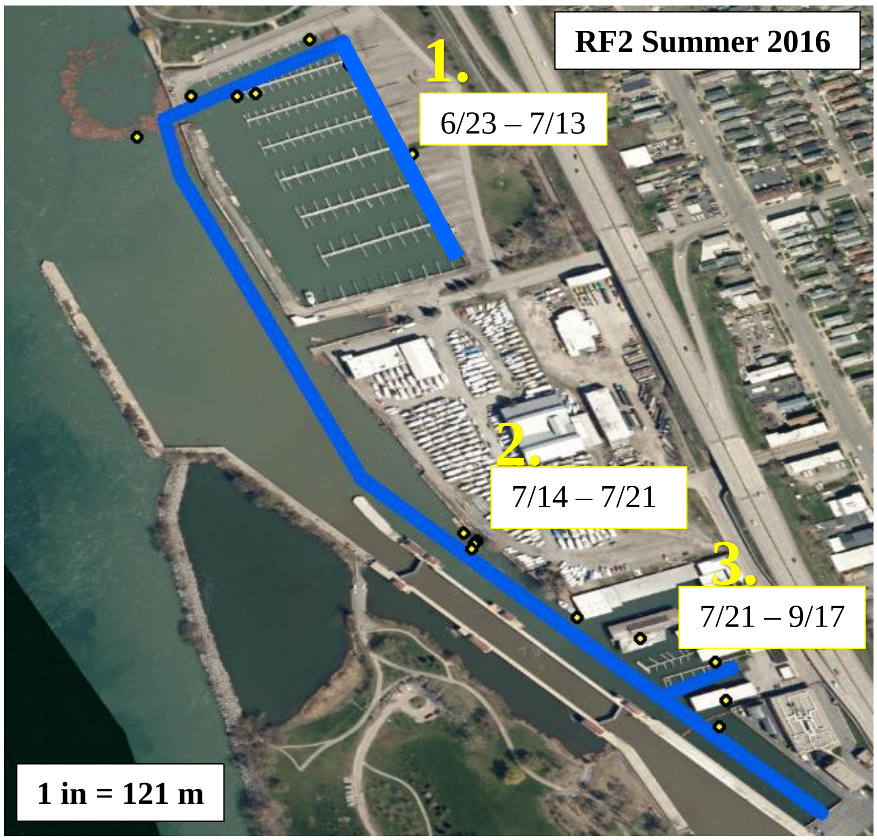

Figure 35. Home range of resident female *G. geographica* (RF2) in the summer of 2016.

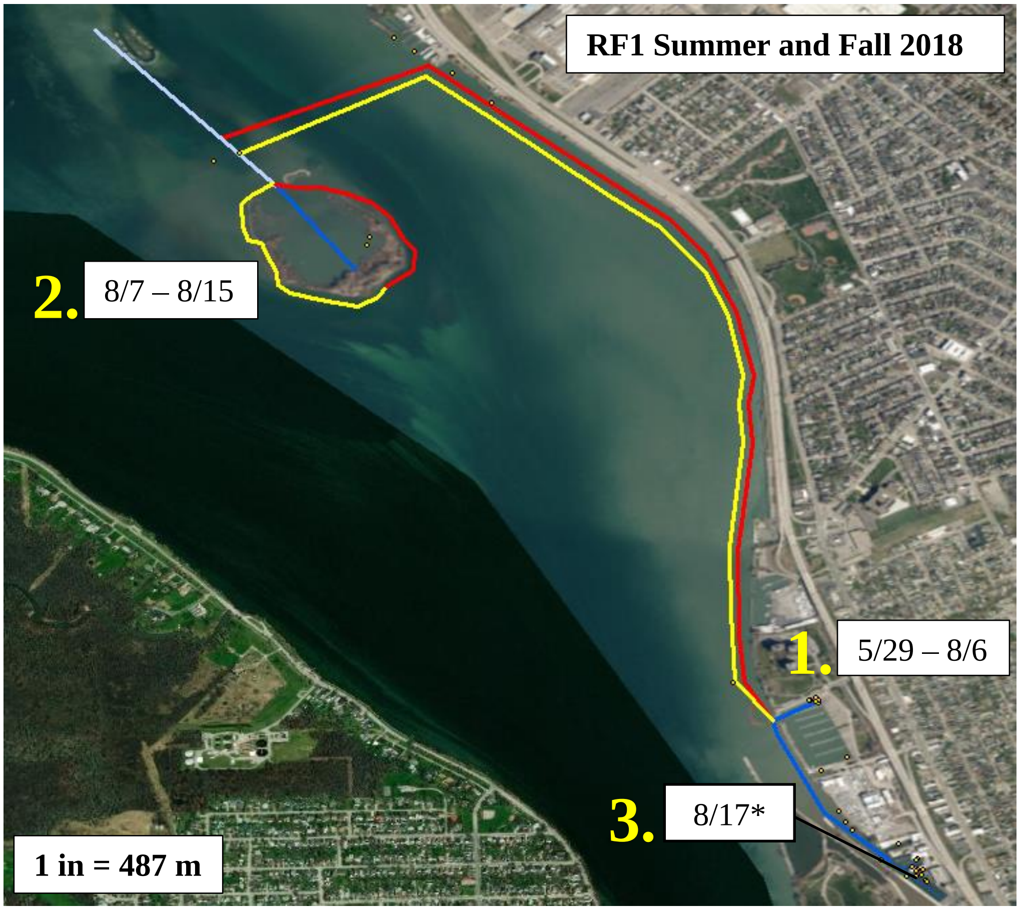

Figure 36. Home range of resident female *G. geographica* (RF1) in the summer and fall of 2018.

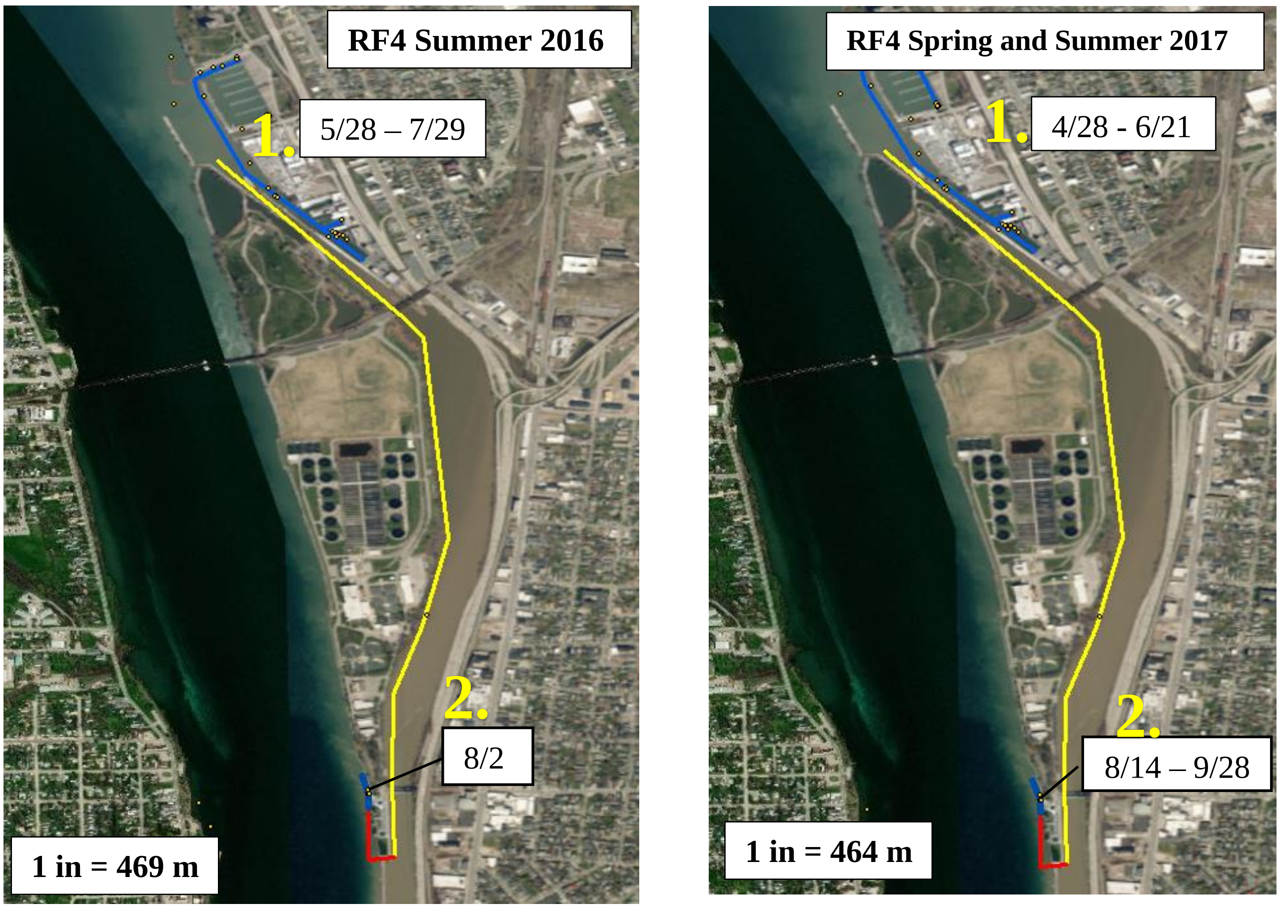

Figure 37. Home range of resident female *G. geographica* (RF4) in the summer of 2016 and the spring and summer of 2017.

Figure 38. Home range of resident female *G. geographica* (RF4) in the active season of 2018.

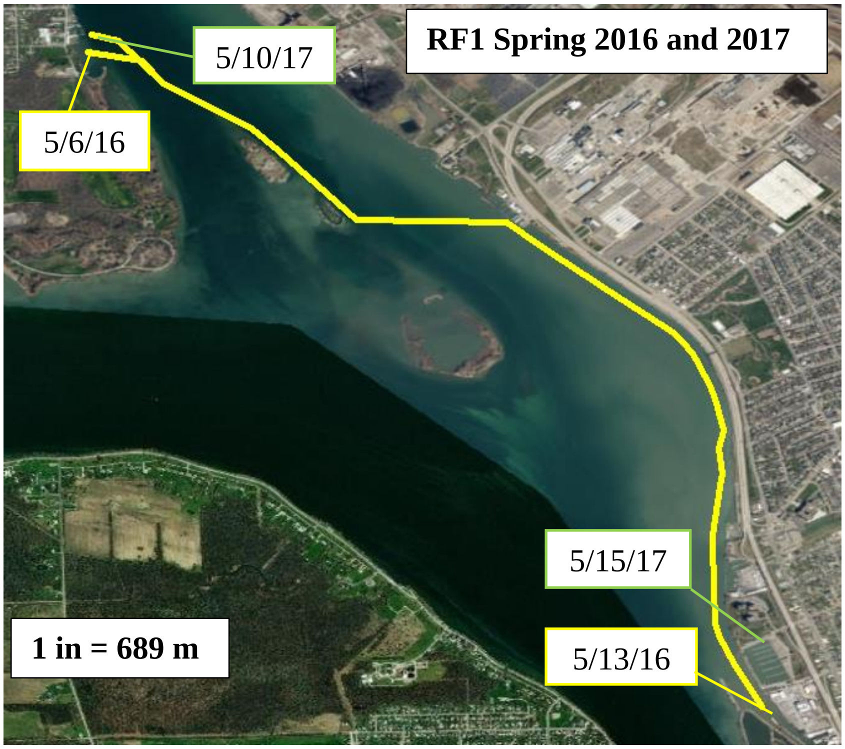

Figure 39. Home range of resident female *G. geographica* (RF1) in the spring of 2016 and 2017.

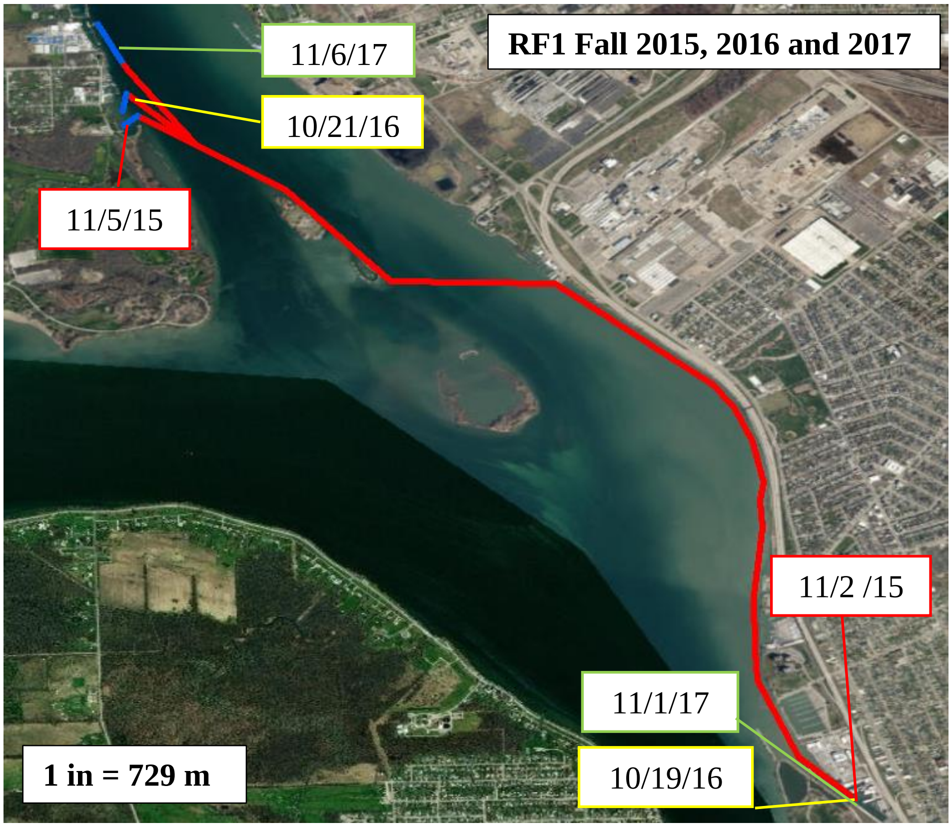

Figure 40. Home range of resident female *G. geographica* (RF1) in the fall of 2015, 2016 and 2017.

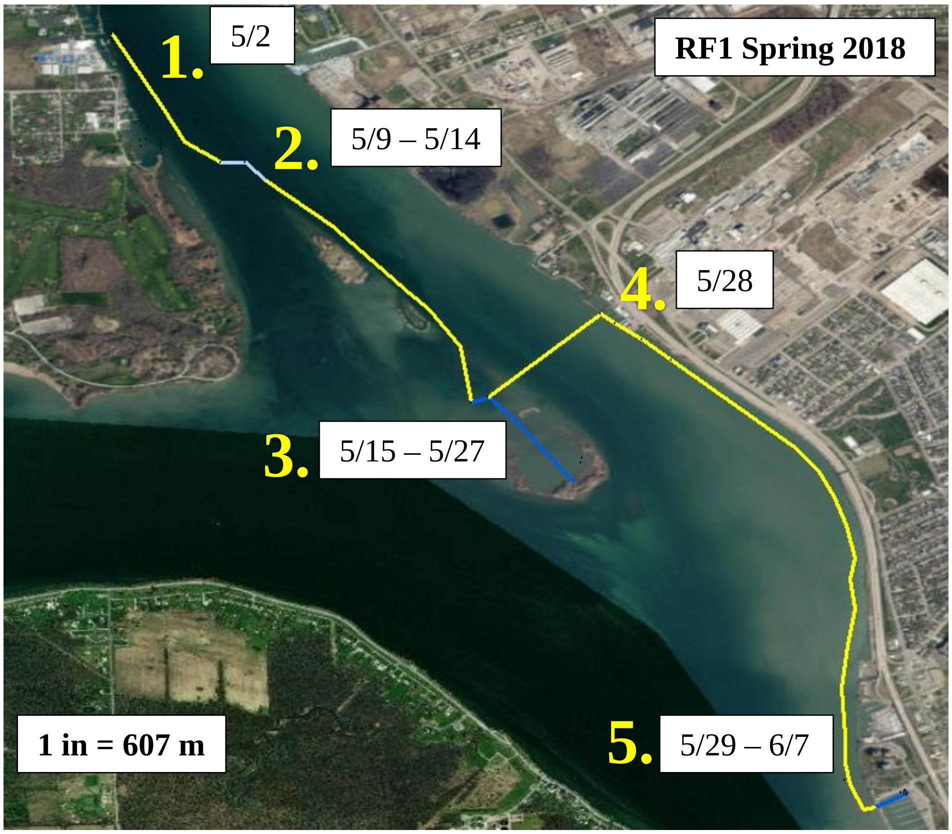

Figure 41. Home range of resident female *G. geographica* (RF1) in the spring of 2018.

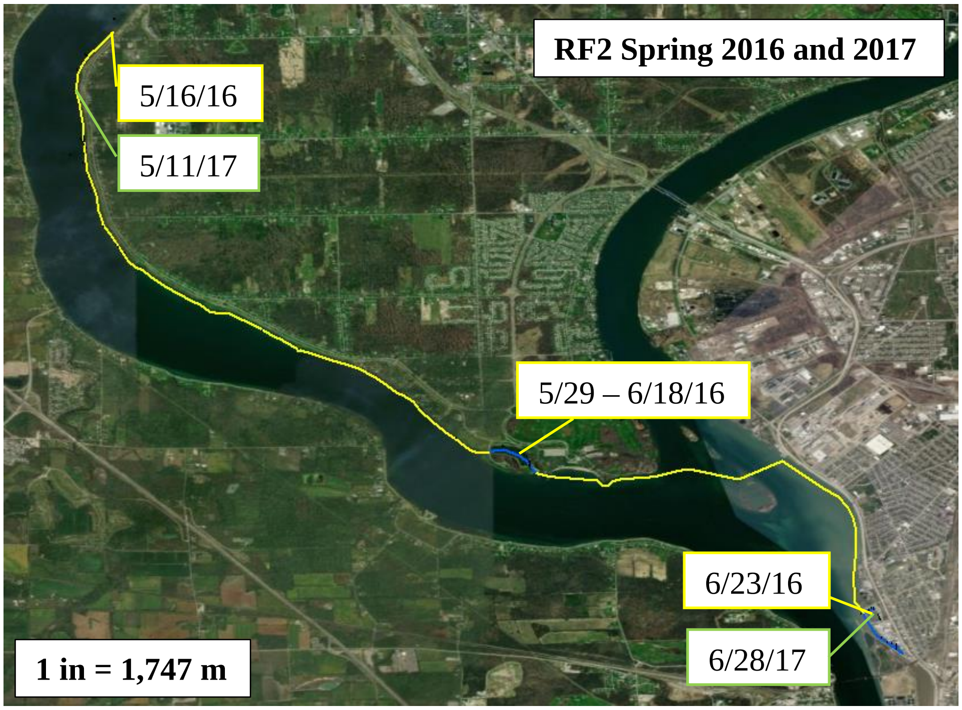

Figure 42. Home range of resident female *G. geographica* (RF2) in the spring of 2016 and 2017.

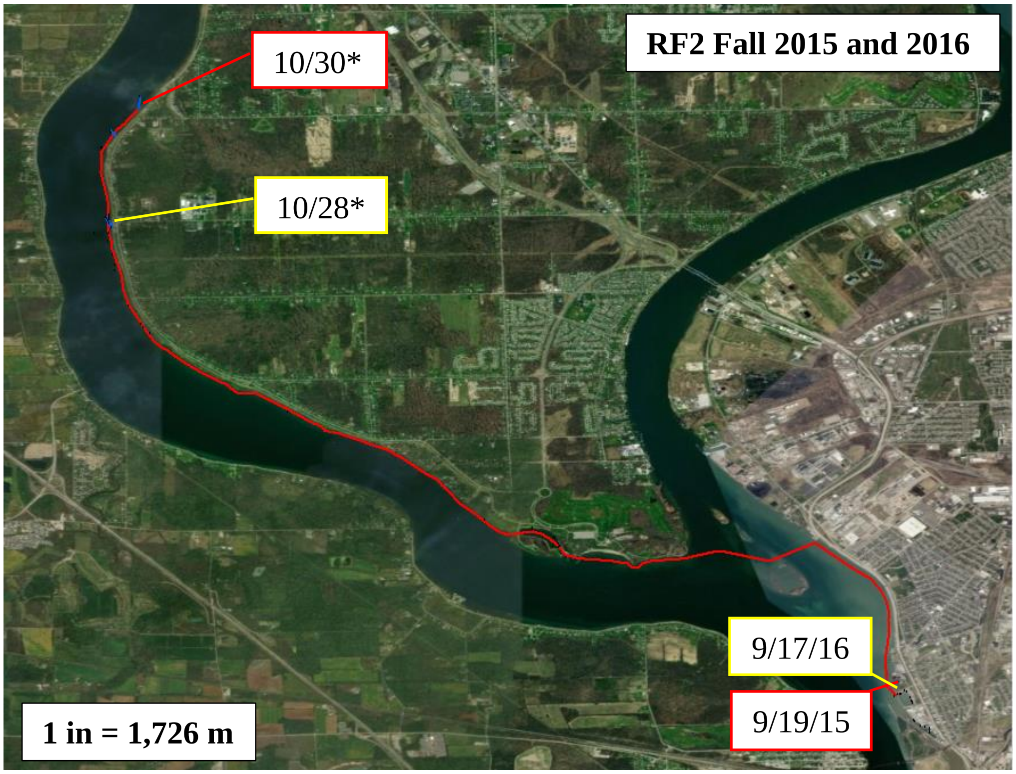

Figure 43. Home range of resident female *G. geographica* (RF2) in the fall of 2015 and 2016.

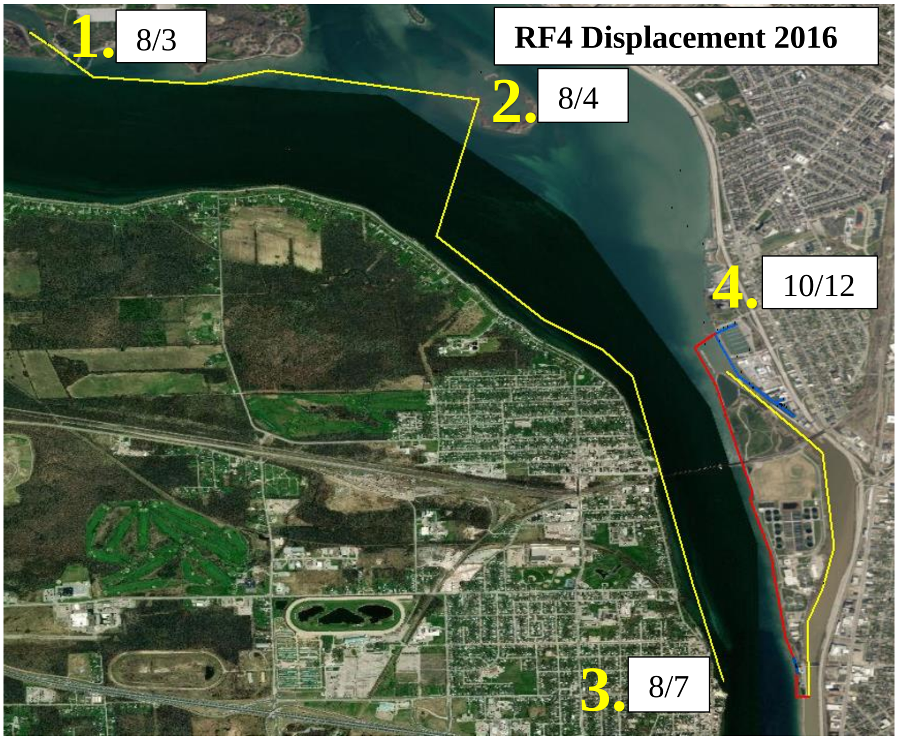

Figure 44. Home range of resident female *G. geographica* (RF4) in the active season of 2016 and the swimming path associated with her displacement during the summer.

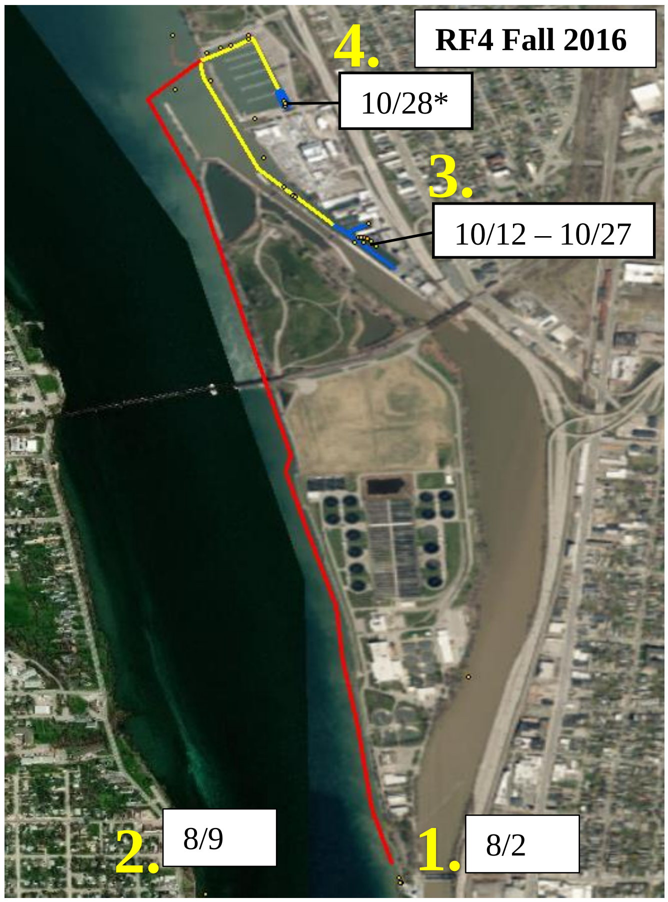

Figure 45. Home range of resident female *G. geographica* (RF4) in the fall of 2016.

Figure 46. Home range of resident female *G. geographica* (RF4) in the fall of 2017.

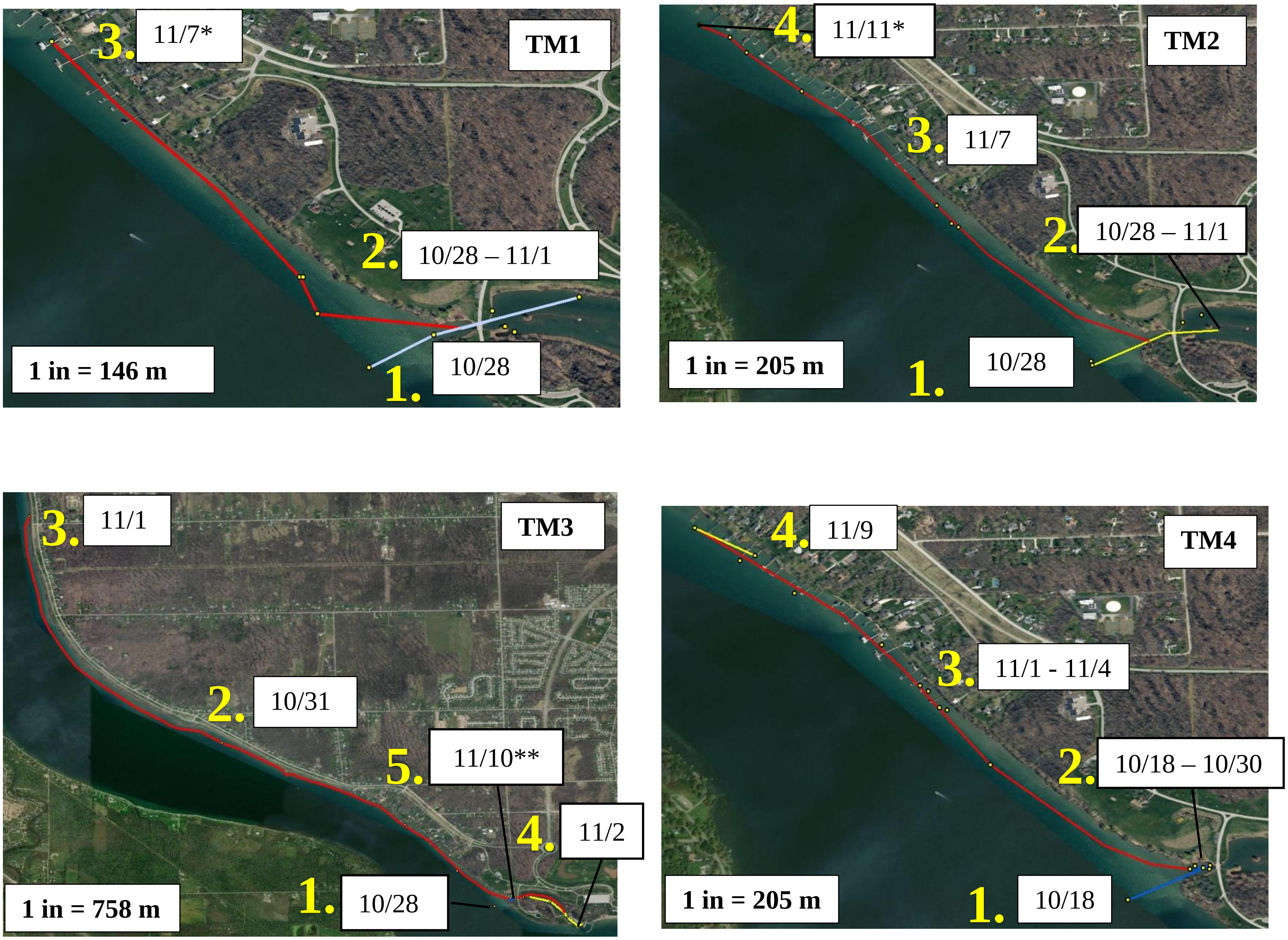

Figure 47. Home ranges of four translocated male *G. geographica* in the fall of 2016.

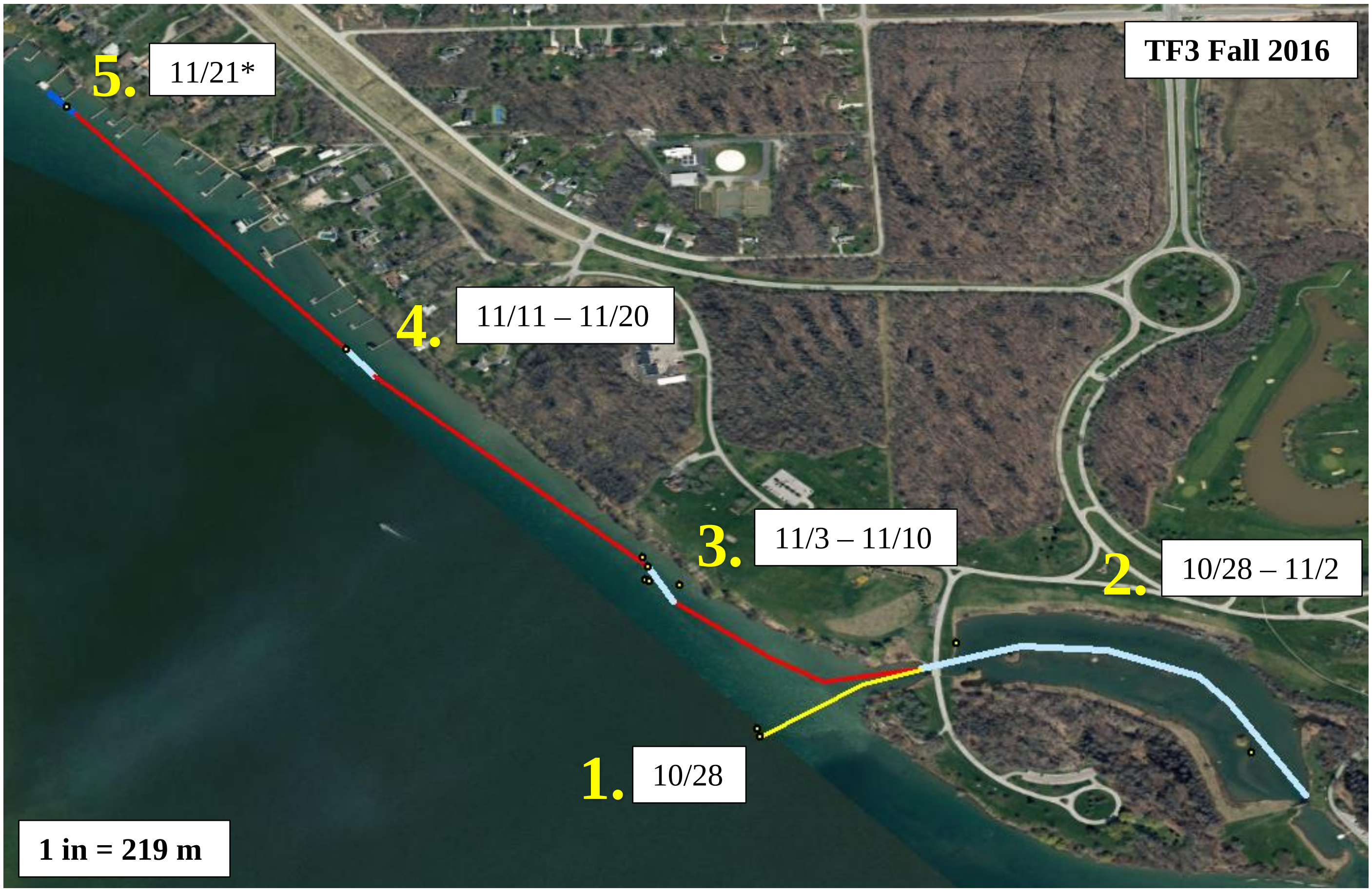

Figure 48. Home range of translocated female *G. geographica* (TF3) in the fall of 2016.

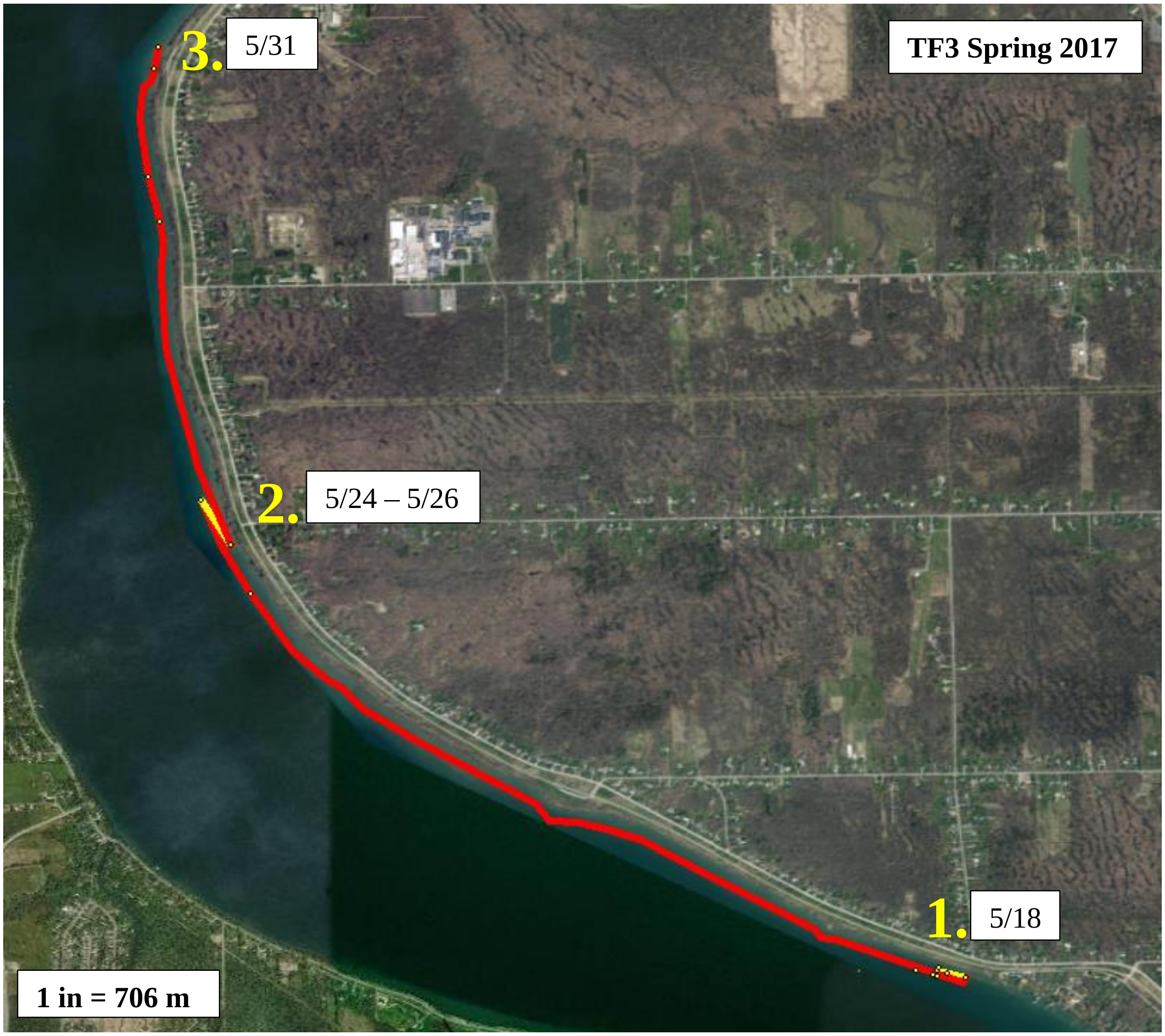

Figure 49. Home range of translocated female *G. geographica* (TF3) in the spring of 2017.

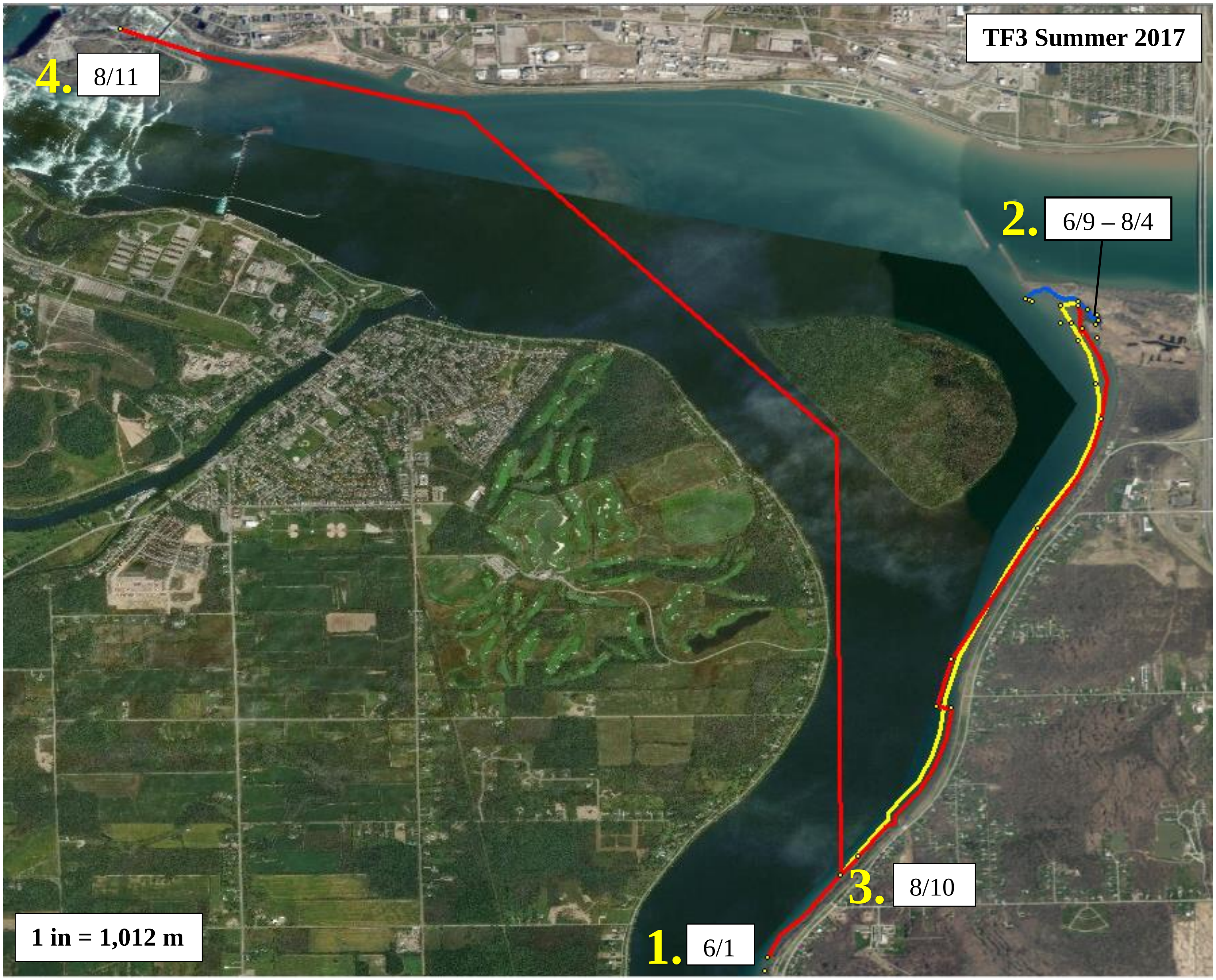

Figure 50. Home range of translocated female *G. geographica* (TF3) in the summer of 2017.

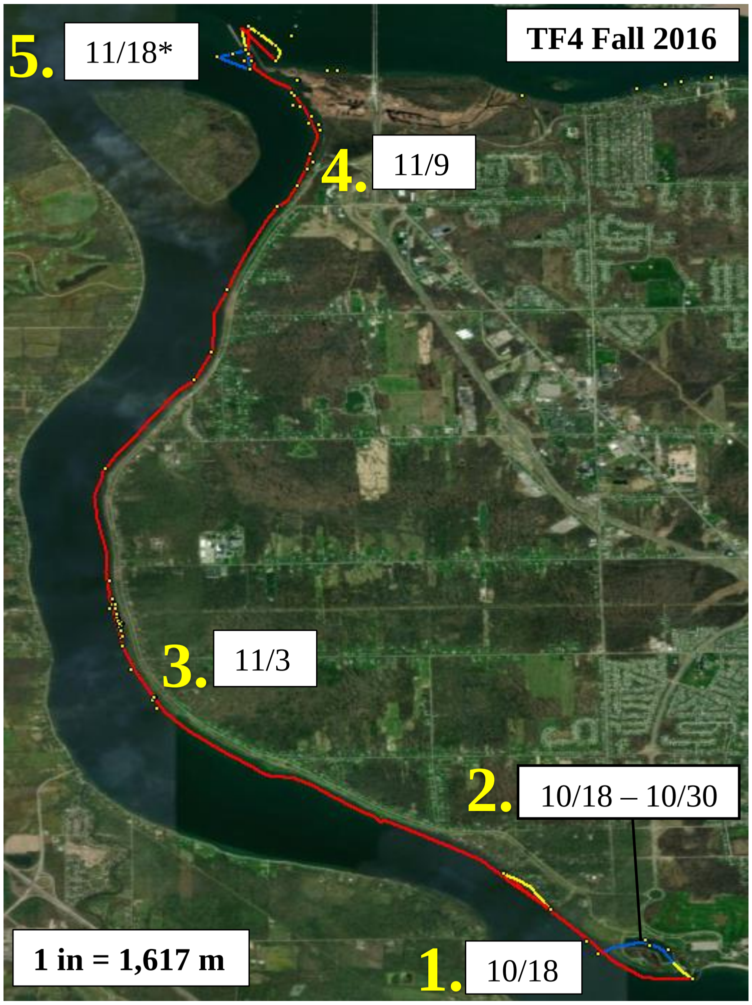

Figure 51. Home range of translocated female *G. geographica* (TF4) in the fall of 2016.

Figure 52. Home range of translocated female *G. geographica* (TF5) in the fall of 2016.

Figure 53. Home range of translocated female *G. geographica* (TF6) in the fall of 2016.

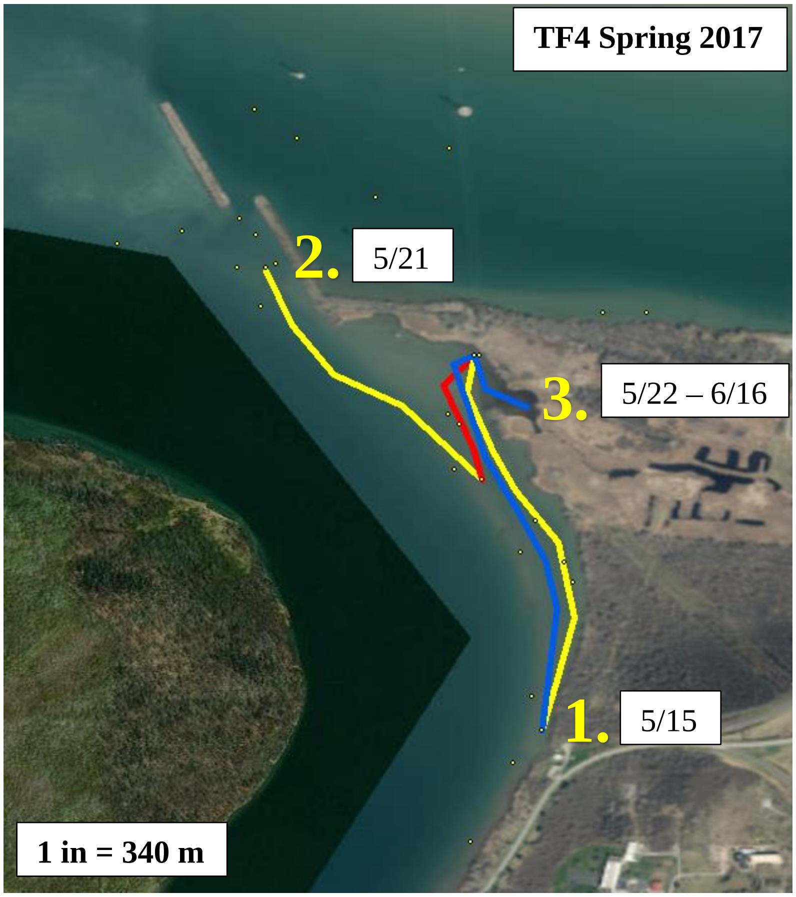

Figure 54. Home range of one translocated female *G. geographica* (TF4) in the spring of 2017.

Figure 55. Home range of one translocated female *G. geographica* (TF4) in the summer of 2017.

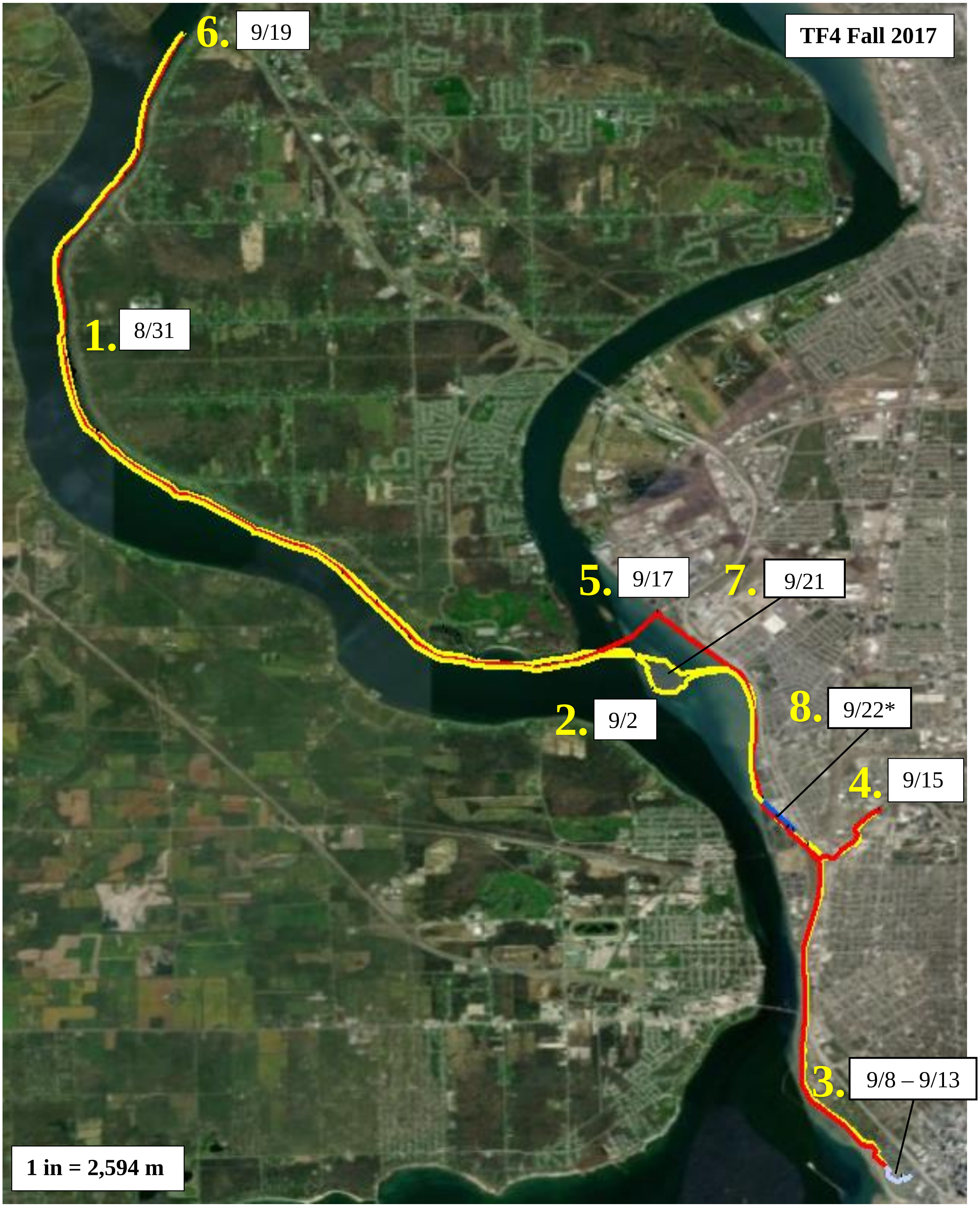

Figure 56. Home range of one translocated female *G. geographica* (TF4) in the fall of 2017.

Figure 57. Home range of translocated female *G. geographica* (TF5) in the spring of 2017.

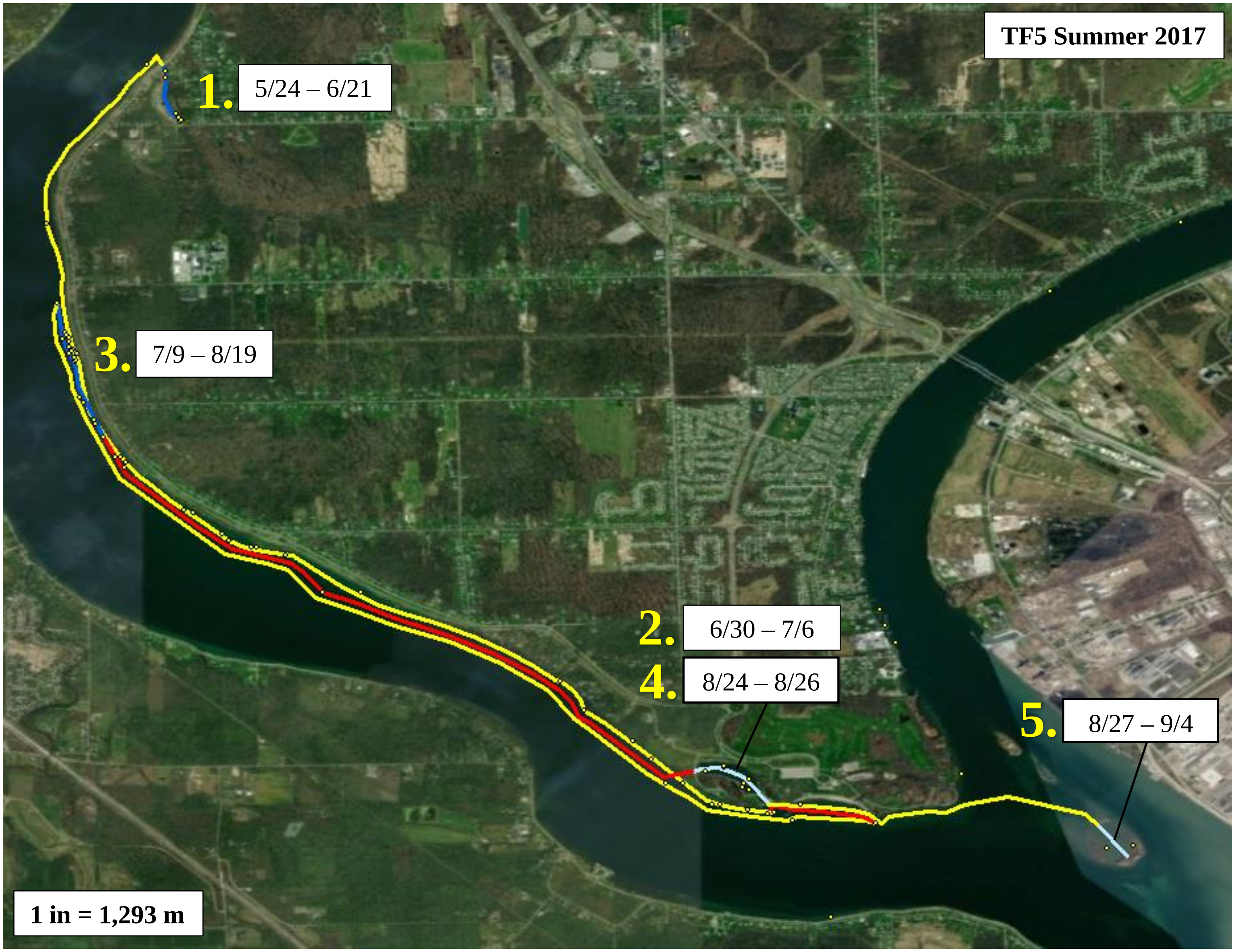

Figure 58. Home range of one translocated female *G. geographica* (TF5) in the summer of 2017.

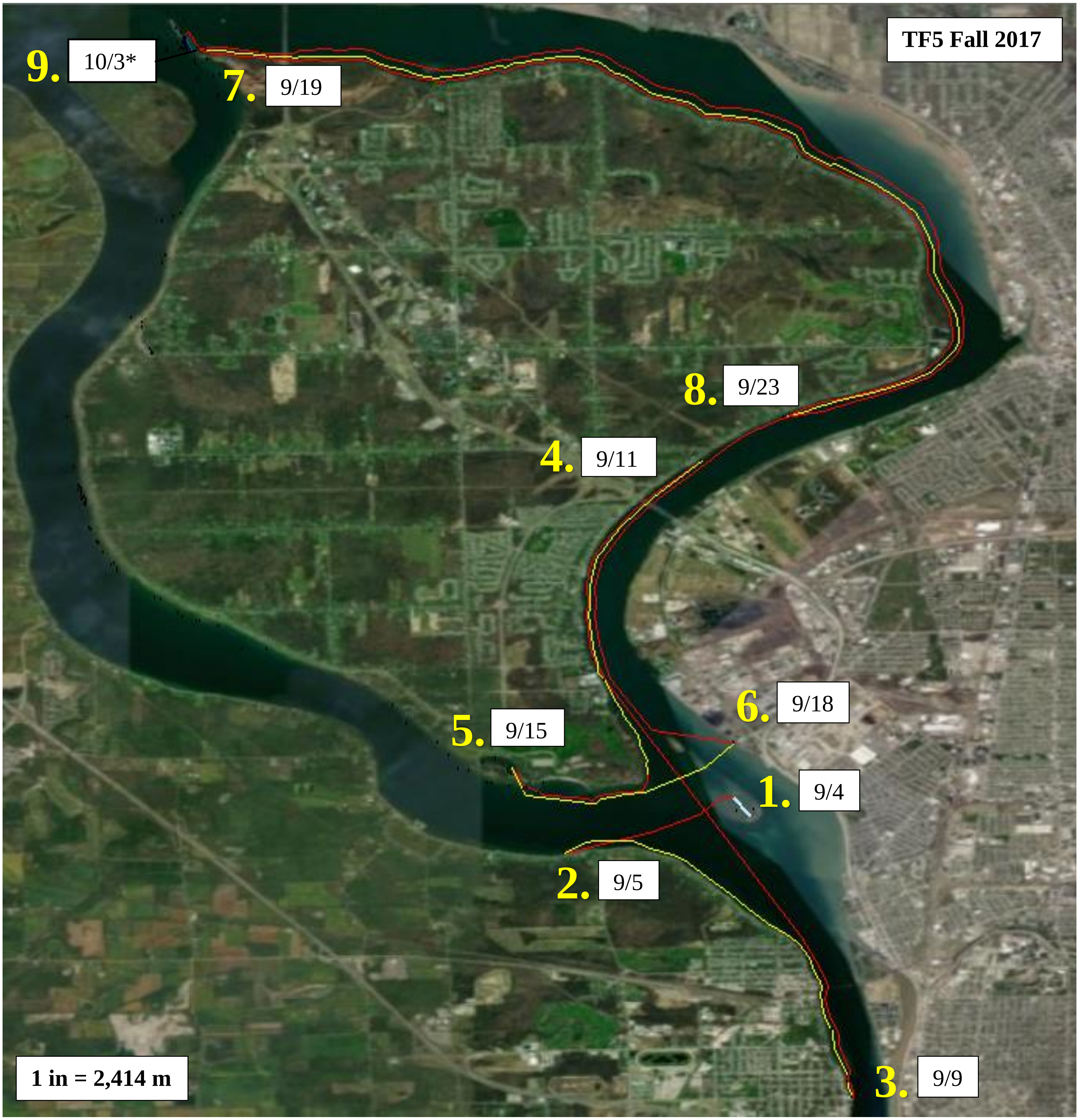

Figure 59. Home range of translocated female *G. geographica* (TF5) in the fall of 2017.

Figure 60. Home range of translocated female *G. geographica* (TF5) in the spring of 2018.

Figure 61. Home range of translocated female *G. geographica* (TF6) in the spring of 2017.

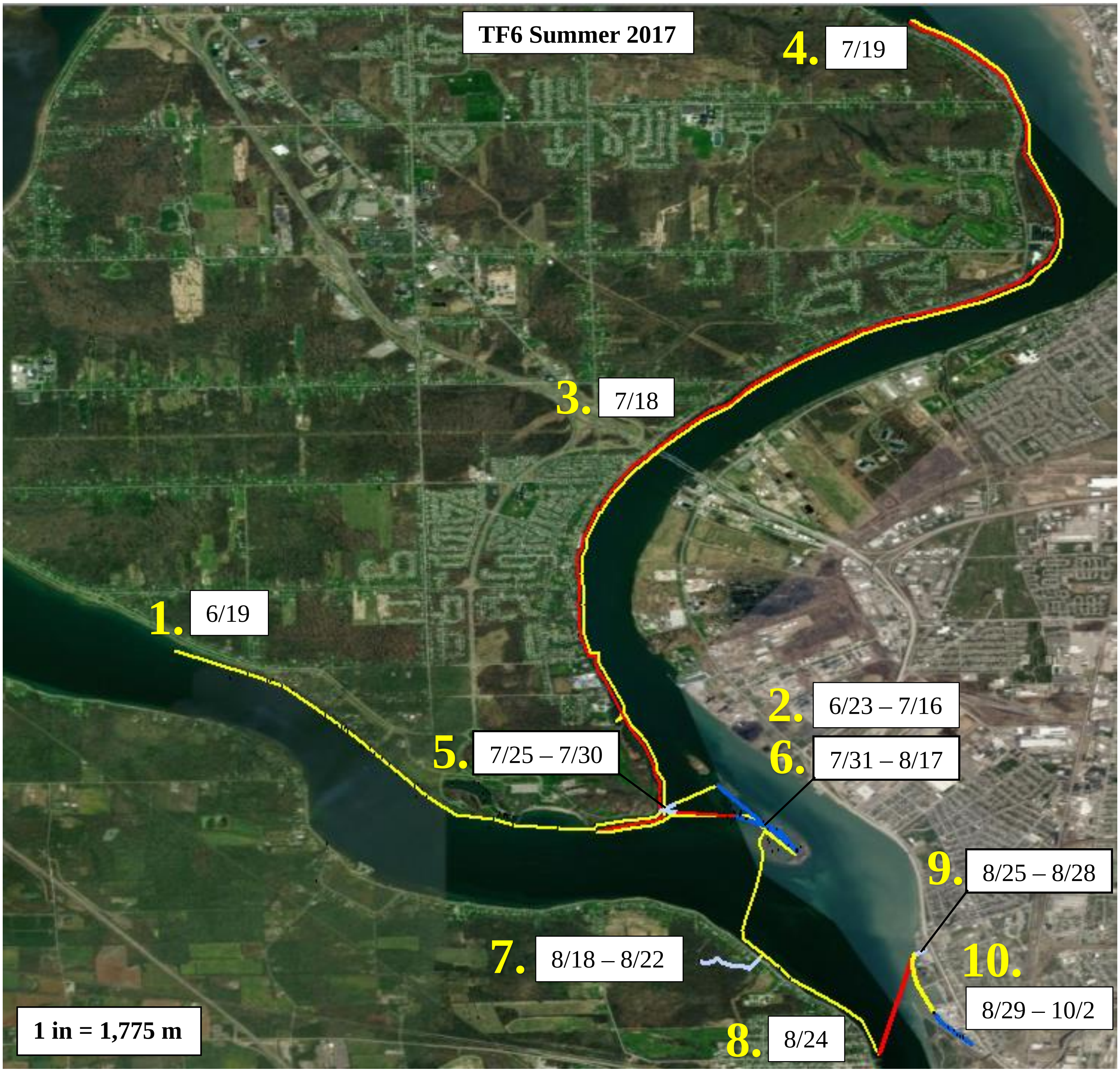

Figure 62. Home range of translocated female *G. geographica* (TF6) in the summer of 2017.

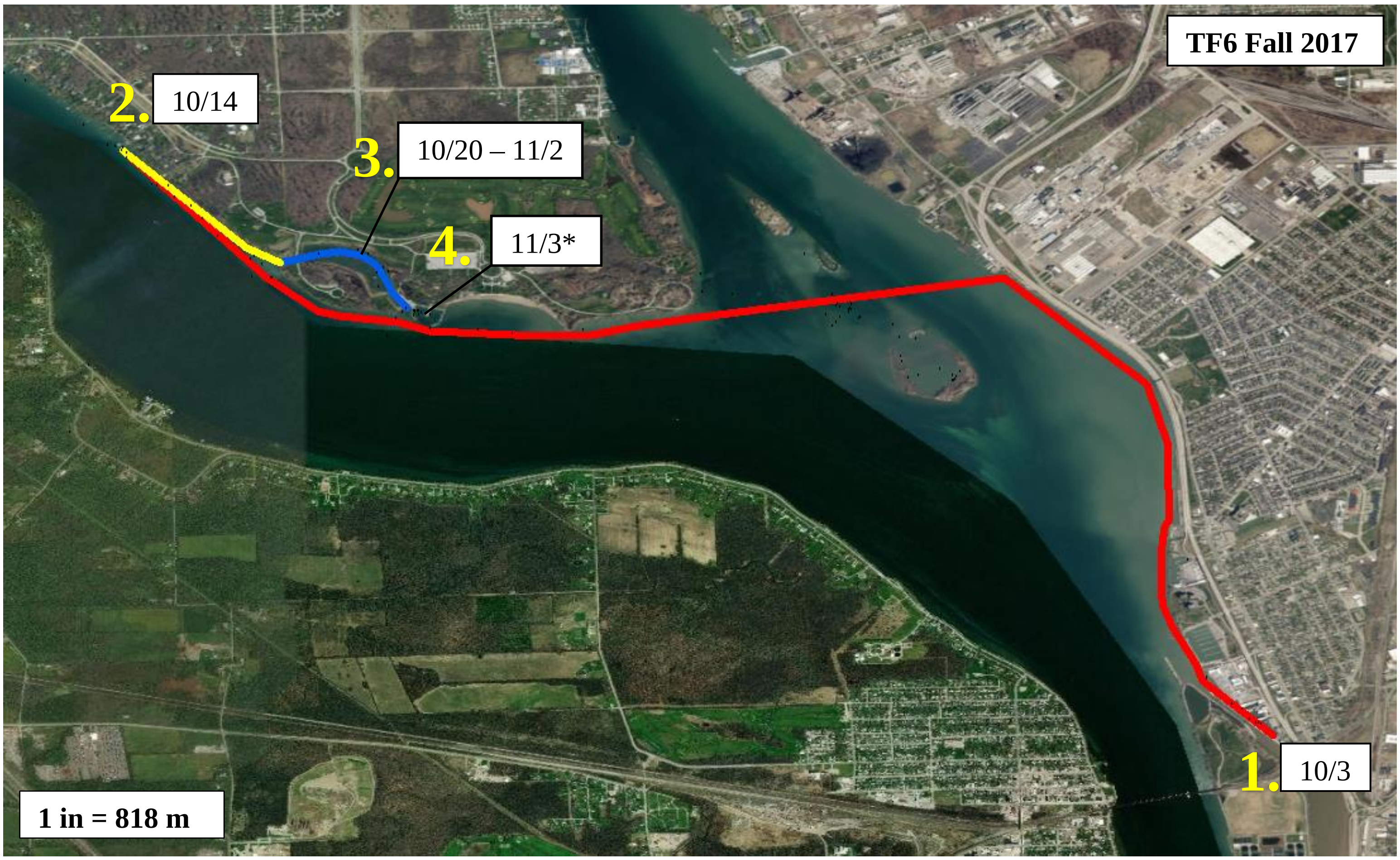

Figure 63. Home range of translocated female *G. geographica* (TF6) in the fall of 2017.

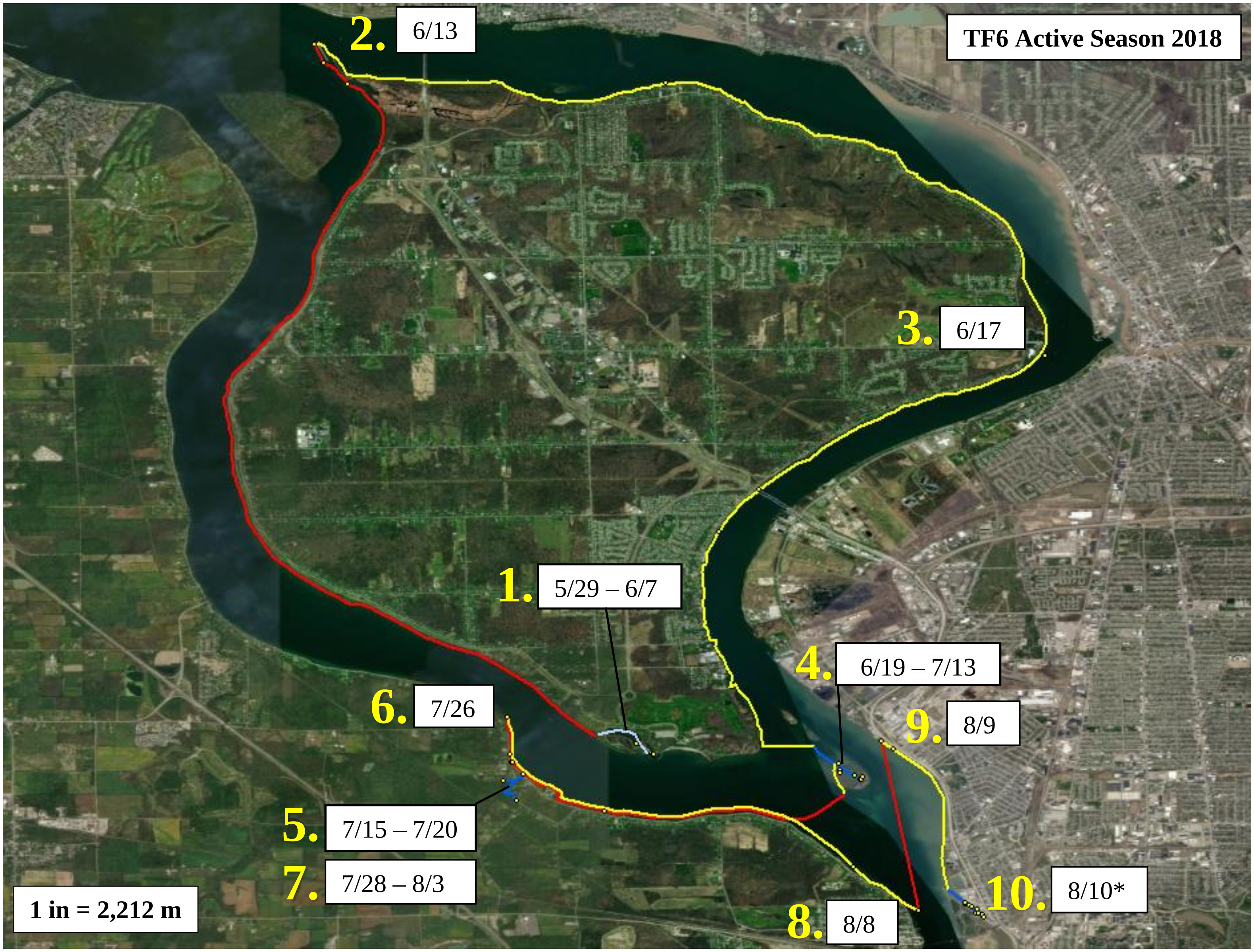

Figure 64. Home range of translocated female *G. geographica* (TF6) in the active season of 2018.